AGRICULTURE

PRACTICAL AND SCIENTIFIC

BY

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London

MACMILLAN AND CO.

AND NEW YORK

1895

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INTRODUCTION

Agriculture is the art of cultivating the soil so that it may produce crops for the use of men or the domestic animals, but in its widest sense it must also be taken to include the breeding, feeding, and management of all kinds of farm live-stock.

The present work will not attempt to deal with the latter part of the subject, but will confine itself to the consideration of the soil, its improvement and management, and the cultivation of the chief farm crops.

Though Agriculture is an art and not a science, yet almost all the principal sciences have a direct bearing upon it. One of the most important in this respect is Chemistry, which is useful to the farmer by showing him the composition of the soil, and the condition in which its various constituents exist; the composition of the crops, and of the various manures and feeding stuffs which he is frequently compelled to use, and so shows, more or less perfectly, their value for nourishing plants and animals. It also explains many changes occurring in the soil, affecting its condition, and is of great use in detecting the adulteration of impurity of those substances which the farmer has to buy, or of those which compete against him in the food markets of the country. Then, again, Vegetable Physiology and Botany are of the greatest service, the former by explaining the

various processes of vegetable life, how the plant lives, feeds, and grows, in this way indicating the conditions which the farmer should try to secure for the growth of the crops; the latter by helping in distinguishing injurious plants and weeds, by explaining the life history of various plant parasites and fungoid diseases, also occasionally by giving a clue to the value of particular plants with which we are unfamiliar, or to the conditions required for their growth, by showing the relationship between them and other better-known species. In the same way Animal Physiology is useful to the stock-owner, by explaining to him the normal processes of animal life, how the animal can digest and assimilate its food, and under what conditions it will make the best use of it, and thus will indicate how the health of the stock may best be maintained. Veterinary science is also evidently of advantage to farmers, by explaining to them the nature of disease and the general principles of treating it. Thus, while it cannot be expected that farmers can find time to become veterinary surgeons, yet such a knowledge of veterinary science may easily be acquired as will enable them to recognise the first symptoms of sickness with greater certainty, and later on to carry out the advice of the veterinary surgeon intelligently. Zoology is also useful on the farm, particularly that part of the subject known as Entomology, which treats of insects, and those branches which deal with the various animals injurious to farm crops and stock. The farmer, and perhaps still more the land-agent, will find a knowledge of Geology useful, by giving assistance in questions connected with water supply, and by indicating where good road or building stone and other useful materials are likely to be obtained. Some knowledge of it will also give a rough indication of the character of soil that may be expected in a district, but, as will be pointed out later on, this cannot be absolutely relied upon. Again, to be thoroughly equipped, a farmer

should have some knowledge of Physics and Mechanics, which will enable him to understand the principles of machinery, how power may be best applied, and other questions of the same kind.

In addition to these sciences there are one or two arts that are of use on the farm or estate, such, for instance, as Surveying, that is, the art of measuring and mapping out of land; Mensuration, which will teach the farmer how to measure work; and Building Construction, which perhaps chiefly affects the land-agent.

It is obviously impossible for any farmer to master all these subjects thoroughly, particularly as farming is a business requiring for its success a long special training in its practical details, but still, some knowledge of the principles of all of them is required if the most economical results are to be obtained. And even the above-mentioned subjects do not absolutely exhaust the list of those affecting Agriculture. For instance, the sciences of Meteorology and Electricity, which are still in their infancy, have distinct bearing upon farming, and it seems highly probable that in the future the increase of knowledge in these subjects must lead to an advance in the practice of Agriculture.

CHAPTER I

THE PLANT

As the production of heavy crops—that is, of large, well-formed plants—is the first aim of the agriculturist, it will be best first to consider plant life in general, what all plants require for their healthy growth; and then, later on, we shall be able to see how these requirements may be supplied.

If any of the ordinary plants of the farm be analysed, ten chemical elements will invariably be found in them. These elements form two groups of substances, the organic and the inorganic, which may be separated by heat. If a plant be burned, a great deal of its substance disappears, leaving a greater or less quantity of light-coloured ash. This ash is the inorganic material; what has been driven off by heat is the organic. If we examine these substances a little more closely, we shall find that the organic substances are composed of the chemical elements, carbon, hydrogen, oxygen, nitrogen, and sulphur; while the inorganic matter always contains potassium, calcium, magnesium, iron, and phosphorus combined with oxygen. In addition to these ten elements, a number of others are generally present, but while the plant can dispense with these latter, it is quite unable to exist if any one of the former elements be absent. The elements found in plants are therefore often classified as essential and non-essential.

The element occurring in largest quantity in the dry matter of plants is carbon, and it is also distinctive of all the so-called organic substances. For example, Warington states that in an average crop of meadow grass, weighing 11,200 lbs. per acre, the carbon weighs 1315 lbs., equal to 11·7 per cent of the total weight of the crop, or, exclud-

ing the water contained in it, to 46·6 per cent of the dry material. Carbon is also found combined with oxygen in the form of carbon dioxide in the air, where its presence is due to the decay or combustion of organic substances, and to the effects of animal life and various fermentations. It also occurs in many minerals, chiefly combined with other elements in the form of carbonates, as, for instance, in chalk and limestone, where it is found in the form of calcium carbonate.

Hydrogen is one of the constituents of water, which consists of hydrogen and oxygen combined together, and it also enters into the composition of all common organic substances. It is, however, in the form of water that it is useful to the plant.

Oxygen occurs in the free state in the air; also combined with hydrogen in water, as already stated, and in both these forms it is of use for plant growth.

Nitrogen occurs in enormous quantities in the air, but in a free state—that is, uncombined with other elements—and in this form is inert, and useless to most plants. It has been proved that most plants take up their nitrogen from the soil in the form of nitrates—that is, combined with oxygen and some other element.

The rest of the essential constituents of plants are all obtained from the soil, where they exist for the most part in quite small proportions, though the total quantity of each present in a given area is often considerable.

These elements exist in the plant combined in many distinct forms. Thus, the three elements, carbon, hydrogen, and oxygen, in various combinations form a large number of substances, the most important of which are the carbohydrates (a group of compounds including the starches, sugars, etc.) and the fats. With nitrogen in addition the same three elements form, amongst others, the group of substances called amides, and these four, with sulphur, form the albuminoids, a very important class of compounds found in all plants.

In addition to the essential elements, which every plant must have in order to live, we usually find small quantities of others, which are not actually necessary. One of the most common of these non-essential elements is silicon,

which exists combined with oxygen in the form of silica. In most plants there is a large amount of silica, but it has been proved by experiment that healthy growth can take place in its absence. Sodium again is almost always present, though apparently non-essential: but it seems to have a special use in partially taking the place of potassium in the plant. Perhaps it does not do this, however, in the case of all plants.

It will be seen from what has been stated above that all the elements that are absolutely necessary for vegetable life are to be found, under ordinary circumstances, ready for the plant's use. We must now consider how the plant makes use of these substances, and, beginning with the seed, we will shortly trace its life.

The Seed.—For the present purpose a seed may be defined as a case containing an embryo plant, and a larger or smaller store of plant food for the use of the young plant. The amount of food thus stored up in the seed is a matter of importance, because it regulates to some extent the amount of growth which can take place before the plant is sufficiently developed to support itself, for, it need hardly be said, the reserve of plant food is only meant to support the young plant until it is able to forage for itself. As, however, the plant is for a time entirely dependent upon what is contained in the seed itself, it necessarily follows that all the substances a plant requires for its healthy growth must be contained in the seed. This is actually found to be the case, all the ten essential elements above named being invariably present in the seed. The inorganic constituents are practically ready for use; but the organic constituents are not so. As long as the seed is kept under conditions that do not favour growth it remains unchanged, but as soon as the three requirements for germination are obtained the seed at once shows signs of life. These three requirements are—

1. Moisture.
2. Sufficient warmth.
3. Oxygen.

The temperature most favourable to germination varies in the seeds of different plants.

The first action which takes place in germination is that the seed absorbs a good deal of water, while at the same time some of its carbonaceous material—that is, material containing carbon—combines with the oxygen of the air, and carbon dioxide is given off. A more remarkable change is that a ferment called diastase is produced, which acts upon the starch contained in the seed, converting it into sugar and dextrin. The fat undergoes a similar change, and is also converted into sugar: and at the same time a change takes place in the substances which contain nitrogen. A great part of the nitrogen in the seed is originally in the form of albuminoids, but when germination has begun, these are changed into amides, another instance of a change from an insoluble to a soluble condition. Thus it will be seen that the three chief constituents of the plant food contained in the seed are changed, when germination begins, from an insoluble state to a soluble, and the reason for this is obvious. Up to the time when the seed begins to germinate it is essential that its food material should be preserved with as little loss as possible, and this, under natural conditions, can only take place if the substances are insoluble, for otherwise they would be liable to be washed away by any rain falling upon the seed, and so lost. But when growth commences it is necessary that the food should be transported to that part of the young plant where growth is actually taking place, so that it may be built up to form new material. This transportation can only take place after the food substances have been dissolved in water, for, though solid matter cannot move from one part of a plant to another, liquids can.

While the plant is thus living upon the reserve of food contained in the seed, it produces two "shoots," as they are commonly called, the radicle, or the young root, and the plumule, which forms the upward shoot, and by the time the seed is exhausted it is necessary that both these should have made sufficient growth to be able to obtain food for the plant's sustenance. If by any chance they cannot do this, the plant will die of starvation. A familiar example of this is furnished when seeds are sown too deep in the soil, in which case, if germination takes place at all, it will be impossible for the upward shoot to reach the surface of the

soil by the time the seed is exhausted, so that the plant will die for want of the food it requires from the air.

A perfectly formed specimen of any of the higher plants consists of root, stem, leaves, flowers and fruit, though these three last may not always be present. Every part of the plant is built up of an infinite number of cells—that is, small sacs or cases—containing a jelly-like substance called protoplasm, which is the essential substance of all living creatures, and has been defined as "the physical basis of life." Each single cell in the plant has to some extent a separate life, though, just as in the case of the higher animals, the cells are very much differentiated—that is, they differ very much in their functions and use to the plant. Consequently, though each has its own life, yet each depends to a considerable extent upon the rest, and anything which injures one part of a plant will weaken or destroy the whole.

The Root. The roots of plants are generally, though not invariably, underground, and they differ very much in their appearance, some being large, thick, and fleshy, others being fine and fibrous; but in all cases we find certain characteristics presented, no matter what the appearance of the roots may be. The function of the root, taken as a whole, is, first, to obtain food from the soil; secondly, to support the plant, and hold it firmly in the ground. It is always the finer roots which are most active in obtaining food for the plant, and it is they which grow most rapidly and ramify through the soil completely. The thicker and older roots are generally useful to the plant only for support. The structure of the finer roots is very interesting. They are of course composed of cells just like the rest of the plant, and it is essential for their usefulness that growth should take place continually, in order that the extreme tip of the root, which has the greatest power of feeding upon the soil, should continually push forward into fresh soil, and come into contact with fresh plant food. But the root fibres are naturally very delicate and ill-suited for pushing their way through hard soil; so to provide against this difficulty, each is fitted at its tip with a cap of much harder, tougher material than that of which the root fibre itself is composed. In order to enable this to penetrate the soil without fear of injury, the growth of the root takes place, not at the extreme tip, as is the case

with those parts of the plant which are above the surface, but at the point just behind the root-cap, where naturally there is much less risk of injury, and consequently the newly formed tender material has opportunity given it to become harder and stronger.

The plant food obtained from the soil is taken up in solution by the root, and one of the chief points to be remembered in considering the growth of plants from an agricultural point of view is that no plant has power to take up food by its roots in any other way. Every substance in solution cannot obtain access to the plant, for it is only those which are diffusible—that is, which have the power of passing *through a membrane*—which the plant can take up. This process of diffusion through a membrane is called osmosis, and it takes place only at the ends of the roots and of the root hairs. The solution of plant food in the soil passes more or less rapidly through the membranous walls of the cells composing the plant, and at the same time that this osmosis is taking place into the plant a similar diffusion is taking place out of it, the juice contained in the cells passing very slowly out through the cell walls. At first sight this action appears to be unimportant, but actually it is of some value to the plant, for the juices are slightly acid in character, and consequently, on coming into contact with the soil, they help to dissolve various constituents of it which otherwise would not be available for the plant's use.

The presence in the plant of comparatively small quantities of the non-essential elements of plant food suggests the question: How does the plant select its food? or rather, Has the plant a power of selecting one kind of food in preference to another? It has been stated that the roots take up plant food in solution by a simple process of diffusion through the membrane forming the covering of the root hairs. At first sight it would appear from this that the plant would take up all the substances dissolved in the water of the soil which surrounds its roots in proportions regulated only by the diffusibility of those substances—that is, that it would take up the largest quantity of the substance which had the power to diffuse most quickly through a membrane, and would take up least of all the substance diffusing most slowly. To some extent this is true; but

besides depending upon the rate of diffusion of the different substances, the requirements of the plant control very largely *the amount of each that the plant takes up. If in the water* of the soil there is a substance which the plant requires in large quantity, directly that substance has diffused into the plant it will be utilised and built up into the permanent structure of the plant, and consequently a further supply of that substance will be taken up at once; whereas, in the case of a substance not required by the plant, the diffusion *must necessarily be slow*; thus, while there is no absolute power of selection that would enable the plant altogether to refuse unnecessary or injurious substances, yet there is a considerable power of choosing out in largest quantity those substances which are of the greatest use for plant growth.

The Stem.—When the solution of plant food has obtained *access to the interior of the root*, it passes along it and so reaches the stem, and eventually all parts of the plant. The function of the stem is in most plants primarily to carry the leaves and flowers, to hold them up and expose them to the light and air. It also incidentally serves to connect the various parts of the plant together; also, in many species, as a storehouse where reserves of food material are laid up. Generally speaking, the flow of sap—that is, the nutritive juice of the plant—is upwards through the stem, viz. from the root to the leaves; but this is not always the case, the actual direction being usually towards the part of the plant which is growing most rapidly. Where growth is taking place, food material is required for the formation of new cells, and consequently, lateral movements from one part of the plant to another may often be detected, as growth is more rapid on one side of the plant or on the other. The general upward flow of sap is at first difficult to account for, taking place as it does against the force of gravity. It may, however, be explained, first, by the fact that diffusion takes place much more rapidly into the roots than out of them, so that a certain pressure is caused within the roots; secondly, by the constant transpiration of water from the leaves of the plant, requiring a continual fresh supply to take its place; and, thirdly, to some slight extent by movements of the stem, which may force the water in

one direction or another by compressing some cells more than others.

The Leaves. The leaves of a plant are the organs by which it feeds upon the air, taking up carbon dioxide, a gas always found in the air, and breaking it up, utilising the carbon and setting free the oxygen. This action, however, only takes place in the leaves of green plants, and only when the plant is exposed to a strong light. It appears that the green colouring matter, known as chlorophyll, is the essential agent in this action, and consequently in plants, or parts of plants, which contain no chlorophyll we find no power of feeding upon the carbon dioxide in the air. The carbon taken up in this way apparently combines with water, and forms one of the substances known as carbohydrates. It is generally considered that the first substance formed is one of the sugars called glucoses, but it has recently been suggested that cane sugar is first formed.[1] Whichever be actually formed, the leaf takes of it what it requires for its own use, its growth and respiration, and the remainder not required by the leaf changes into starch. This requires a comparatively slight change in chemical composition, as starch and glucose are both carbohydrates, and are therefore very similar substances. The starch so formed is stored up in the leaf, and remains there until it is required for use in some other part of the plant, when, in order that it may be transported from the leaf to the point required, it is necessary for it to become soluble, so that it may easily be carried in solution in the juices of the plant. Accordingly, the starch is converted once more into glucose, the conversion apparently being effected by diastase—that is, the same ferment which converts starch into sugar in the germination of the seed. It has been shown that diastase is present in almost all parts of plants, though in very variable quantities. Generally speaking, the quantity of diastase is greater when there is the smallest quantity of starch present, as, for example, when the plant has been kept in darkness for some time, so that the formation of starch has been checked, and its quantity is consequently small.

In this way it is possible for the plant food obtained from

[1] Brown and Morris, *Jour. Chem. Soc.*, vol. lxiii.

the air to be transported from one part of the plant to another, and when this translocation, as it is called, has taken place, and the food material has arrived at the point of growth where it is to be built up into permanent tissue, it again undergoes a change, taking the form of cellulose, starch, woody material, or whatever substance of the kind may be required.

But besides this action in the leaves of plants there is another constantly taking place, viz. *respiration*, referred to above. The respiration of plants is very similar in its effects to that of animals, for oxygen is taken up from the air, and, combining with some carbonaceous substance in the plant, is given off in the form of carbon dioxide. Thus it will be seen that the plant is at the same time forming carbon dioxide and destroying it; but while the former action is constantly taking place, whether the plant is in light or darkness, the latter, that is, assimilation, only takes place when the plant is subject to a bright light. Respiration, however, is far less important than assimilation, taking place much more slowly, so that the net result of the two processes is that the quantity of carbon dioxide in the air is diminished, while the quantity of the oxygen is increased. It may just be remarked in passing that this effect of plant life is the exact opposite of the result of animal life, animals taking up oxygen and producing carbon dioxide, while plants break up carbon dioxide and give off oxygen.

The formation of nitrogenous substances is not fully understood, but it is probable that first of all amides are formed, as these are capable of being transported from one part of the plant to another, and these amides are afterwards formed into albuminoids, more permanent substances, which, however, could not be transported in solution. For the formation of albuminoids and the protoplasm, sulphur and phosphoric acid are apparently both required, and in seeds there is usually a distinct relation between the quantity of phosphoric acid present and that of the albuminoids.

In all plants, at some period of their growth, more food material is taken up than is required for immediate use, and the surplus is stored up to meet the future requirements, either of the plant itself, or of future generations of the same species. If the reserve is to be used by the plant

itself, it is stored up either in the stem, as, for example, in the case of timber trees and perennial plants generally, or in the root, as in the case of the turnip, mangel, etc., or in tubers, as in the potato; while, if this food is to be used by future generations, it is laid up in the seed, to be used in the manner that has been described when germination takes place.

CHAPTER II

THE SOIL AND ITS FORMATION

SOIL is the term applied to the upper layer of the earth's surface when it is in a sufficiently fine state of division to be suited for the growth of plants. Usually it consists for the most part of mineral matter, with a larger or smaller amount of organic matter or humus mixed with it, the latter consisting of the remains of plants or animals. Of course, under all ordinary circumstances, the soil also contains large quantities of water. The quantity present of each of these three groups of substances can easily be determined, the water being driven off by heating the soil for some time to a temperature of 212° Fahr., and the organic matter by burning, when the residue will consist of the mineral matter only.

As a rule the soil is quite shallow, and at a depth of a few feet or even inches, rock of some kind may be found, either stone, gravel, or clay. There is also generally between the soil and the rock an intermediate layer called the "subsoil," differing somewhat from the soil in texture, colour, and composition.

Almost all soils are formed in the first instance from rocks, by a gradual disintegration or breaking up by various natural agencies. The chief of these agencies is water, which acts in several ways. First, water can dissolve many minerals, and thus may destroy the rocks in which they occur. Moreover, in nature, water usually contains carbon dioxide, which it has dissolved from the air, and then has a distinctly acid action, and consequently an increased power of dissolving many substances.

The mechanical effect of water is perhaps greater than its solvent action, and its power of cutting into even the hardest rock is too well known to need any further notice; but this action is very much assisted when the water carries sand or mud in suspension as it flows over the rock, for in this case the suspended matter scratches the surface of the rock, acting like a file. Again, even when flowing water is not strong enough to actually displace stones in its course, it can often make them rock slightly and rub against one another, in this way gradually wearing them away. Soft rocks, such as clay or sandstone, if exposed to the weather, are very frequently broken up merely by the beating of rain on their surface, instances of which can be seen in many parts of our coasts, where the cliffs are worn away often more by rain than by the beating of the sea upon them. This last agency must not be forgotten, for in many cases the power of the waves of the sea does much to wear away the rocks of the coast.

Besides the direct action of water, as mentioned above, it acts indirectly towards the same end under the influence of frost. As is well known, water expands in the act of freezing, and consequently, if it is imprisoned in the crevices of a rock at the time of freezing it acts as a powerful wedge, and frequently breaks enormous masses off the face of cliffs. This same action of water in freezing not only breaks up large masses of rocks, but gradually pulverises rock already reduced, and in the same way acts upon the soil itself after it is formed, and is therefore a most valuable aid in cultivation. In the form of ice also, water is a powerful agent in disintegration, when, in glaciers, it grinds and crushes to a fine powder the rock over which it passes.

Mere change of temperature, irrespective of actual freezing, is also a very important factor in the disintegration of rocks. Almost all substances expand under the influence of heat and contract in the process of cooling, and this expansion and contraction frequently breaks up rocks where other agencies might fail. In the case of homogeneous rocks—that is, those having an even texture throughout—an increase of temperature may make them split by heating the mass unequally, and so causing one part of the rock to expand more rapidly than another. Naturally a breakage

takes place, just as happens if glass be suddenly heated. Where a rock consists of several minerals distinct from one another, sudden heating may act even more powerfully, owing to the fact that the different substances may expand or contract unequally under the influence of change of temperature, so that the rock is, as it were, torn asunder. Again, in the case of some rocks, the same result may occur from the fact that some crystals expand to a greater extent in one direction than another. The changes of temperature that are sometimes experienced even in this country are much greater than are usually supposed, it being by no means uncommon to find a difference of 50 or 60 degrees Fahrenheit, or occasionally more, between the temperature in the sun during the day and the minimum temperature at night, and where considerable masses of rock are exposed to changes of this kind taking place within a few hours, they are naturally likely to be broken up.

The surfaces of rocks are also acted upon by the mere alternate moistening and drying which takes place when they are exposed to the weather, and under these circumstances they crumble gradually away, though often only to a slight extent.

The air is another important agent in bringing about the disintegration of rocks, acting both chemically and mechanically. Chemically, its effect is chiefly produced by its oxygen combining with other substances and producing softer, bulkier compounds. Mechanically, the action of the air is more important than is frequently supposed, the wind in some cases acting strongly on the surface of rocks, either alone, or still more by carrying dust, and in this way wearing away hard surfaces. The action of the wind, too, assists the action of water, as, for instance, by producing the waves of the sea, or by causing rain to beat strongly on rock surfaces.

Plants growing on the surface of rocks act in several ways. First, mechanically, by sending their roots into the crevices, and then, by subsequent growth, gradually forcing them asunder. Also, by keeping the surface of the rock damp, thus gradually softening it and making it more easily disintegrated. Lastly, chemically, partly by the acid excretions of the roots dissolving rock surfaces with

which they may be in contact, but still more in the production of leaves or other vegetable substances, which in their decay assist in the solution of the rock.

Similarly, some animals help in the breaking up of rocks, chiefly by opening up the soil and allowing air and water to penetrate it more freely. In the case of earthworms, however, besides the above action, the soil is benefited by being passed through their bodies and ground to a finer state of division in the process.

Soils may be divided into two classes:—

1st. Sedentary soils.
2nd. Transported soils.

Sedentary soils are those which have been formed from the rock upon which they rest, by a simple process of disintegration. In this case the soil will have many of the characteristics of the rock below it, but almost invariably it will be darker in colour, owing to an admixture of organic matter, and also partly owing to exposure to the air. The subsoil, too, in such a case will be intermediate between the rock and the soil, both in texture and composition, being in fact imperfectly disintegrated rock.

Transported soils are those which, after their formation, have been carried by water or other agencies and deposited in their present position. The chief agents in this transportation are water, ice, and wind.

The action of water is familiar to every one, the mud carried by every stream after rain being an example of soil in the process of transportation. A further example of the same action, on a larger scale, may be found in the case of many large rivers, notably the Nile, which has not only built up the greater part of Lower Egypt by drawing away soil from the upper part of its course, but is yearly bringing down large quantities of mud in its annual inundation, which it deposits on the surface. This action of the Nile is so extensive as to counteract the gradual subsidence which is taking place in that part of the earth's surface, so that, though the sinking is constantly going on, the level of Lower Egypt is at least maintained. Another example is the Mississippi, which is continually filling up the lower part of its bed, so that it has been found necessary to carry

embankments farther and farther up its banks in order to prevent flooding of the surrounding country. An instance, more important, perhaps, from an agricultural point of view, is the effect of rain in washing soil from hill-sides. This may be most easily seen in the case of arable land, where the constant disturbance of the soil helps the action of the water. The extent of this action can be best realised by observing the difference in the level of the surface of the soil where a hedge or other fence of the kind runs across the slope of a hill. The soil in its passage down the hill is stopped by the fence, and is gradually piled up more and more against the upper side of the fence, while at the lower side the soil gradually works away, leaving the fence higher and higher above the surface. In this way a difference of four or five feet or even more may occur between the levels of the fields above and below a fence in this position.

Where a stream of water carries material and deposits it at its mouth, gradually forming a delta, we find generally a gradual sorting-out of the materials it carries according to the size of the particles. As a river flows into the sea it gradually loses the velocity of its current, and as its speed diminishes its power of carrying solid matter suspended in it decreases. Accordingly, the coarser sediment will be found nearest the mouth of the river, the finer particles being held in suspension longer and carried out farther from the mouth. An example of this in the case of a current of the sea is found at Chesil Beach, where, along the shore of a bay, the pebbles are sorted according to their size, the large ones being at one side of the bay, and gradually decreasing in size towards the other. This is of some importance in connection with the transportation of soils, for it causes soils deposited in this way to vary considerably in their properties, even when derived from the same rock originally, for we may get in the deposit of one stream several distinct kinds of material.

Another agent in the transportation of soils is ice, which acts principally in the form of glaciers, which, after grinding the rocks to a fine powder or mud, carry it with them in their course, either beneath or mixed with the lower layers of ice. When a glacier from any cause disappears, this mud is, of course, left on the surface of the ground, forming a soil.

and in some such manner many of the soils of this country have been formed, as, for example, the boulder clay in the Holderness district of Yorkshire. To some slight extent soil is also transported by ice formed in the course of rivers in the winter. Detritus becomes mixed with the ice in the process of freezing, and, when the thaw takes place in the spring, is carried down in the course of the river to some extent, and deposited in the lower reaches of the stream.

Comparatively unimportant is the action of wind; but in certain cases very light soils may be carried by this means, and occasionally deposits that have been formed in this way are found occupying a considerable area, as is seen in some sand dunes in France.

CHAPTER III

CLASSIFICATION AND PHYSICAL PROPERTIES OF SOILS

Most of the rocks occurring in this country may be divided into three groups, according as they are composed chiefly of clay, sand, or carbonate of lime. In like manner the soils formed from them are divided into three main classes, according to the prevalence of these three constituents. A fourth class also occurs, including those soils which are rich in organic matter. Besides these main groups there are many soils intermediate in composition, and the usual classification adopted is that of Schübler, which is as follows:—

I. Argillaceous, above 50 % clay; under 5 % carbonate of lime.
II. Loamy, 30 to 50 % clay; under 5 % carbonate of lime.
III. Sandy Loams, 20 to 30 % clay; under 5 % carbonate of lime.
IV. Loamy Sands, 10 to 20 % clay; under 5 % carbonate of lime.
V. Sandy, under 10 % clay; under 5 % carbonate of lime.
VI. Marly, 10 to 50 % clay; 5 to 20 % carbonate of lime.
VII. Calcareous, above 20 % carbonate of lime.
VIII. Humous, above 20 % of humus.

Even this, however, cannot be taken in a rigid manner, for soils commonly called loams, for example, frequently contain proportions of clay differing from those stated in the table. For instance, soils containing 60 and 70, and even 75 per cent of clay, are often classed by practical men as strong loams. A further class of soils not included in the above table is that of the calcarenes, which consist of sand with a considerable proportion of carbonate of lime. If a moderate amount of clay be mixed with a calcarene, the soil is called a sandy marl.

In ordinary language soils are usually classed as "light"

and "heavy"—"light" soils being those which are porous and friable, and so open in texture as to offer little resistance to the passage of implements through them. They may consist chiefly of sand, or of chalk, or of limestone, or of humus, and consequently may vary very much in different examples. The "heavy" soils, on the other hand, are those which are close in texture and of a sticky nature, so that the labour of cultivation is considerable. All the heavy soils resemble one another in containing a large proportion of clay. The terms "light" and "heavy" have no relation at all to the actual weight of the soil, for in this particular sand is first, clay being considerably lighter, and carbonate of lime and humus lighter still. At first sight the weight of the soil seems an unimportant particular, but it must sometimes be taken into account in calculating the amount of any constituent of the soil present in a given area. A substance occurring to the extent of 1 per cent in a sandy soil will, of course, be present in a much larger quantity per acre than if it occurred in the same proportion in a humous soil.

The proportions of clay, sand, lime, and humus in the soil affect its other physical properties to an important extent, *particularly its relation to moisture*. Most soils have the power of absorbing moisture to some extent from the air, and the greater this power the less the crops grown on the land will suffer from drought. It is found, however, that pure sand has no power whatever of taking up moisture in this manner: carbonate of lime has some power, clay still more, and humus the greatest capacity for absorbing moisture. A difference is also found in the relative speed with which soils become dry, sand becoming dry most quickly, humus least quickly. The amount of water a soil can hold mechanically has also an influence on its value. Humus has the greatest power, next to that clay, and sand least of all. This, however, depends to some extent on the size of the particles of the soil, a fine sand retaining more water than a coarse one.

All soils have the property of raising water from the subsoil by what is called capillary attraction—that is, by a process of drawing up the moisture, just as blotting paper will suck up a blot of ink. This has great influence on

the fertility of the soil, and particularly on the extent to which it suffers from drought, for the greater the capillary attraction of the soil, the less crops will suffer in dry weather. The extent of this power depends on the size of the particles of the soil. The smaller the particles are, and the closer they are together, the greater the capillarity. Very fine clay has the greatest capillary power, humus rather less, and sand the least. It may be noticed with regard to sand that what is usually called a "sharp sand"—that is, a sand composed of angular fragments—has greater capillarity than a water-worn sand, in which the particles are rounded.

The extent to which the soil contracts on drying affects the crops growing on it, for in the process of contraction it compresses the roots of the plant, and when it cracks tears them asunder. Peaty soils contract most on becoming dry, and clays almost as much. Sand, on the other hand, does not contract at all.

The relation of the soil to heat influences plant growth very much, and therefore the power of the soil to absorb heat is of great importance. It depends partly on the colour of the soil, partly on its heat capacity, and partly, as far as its lower layers are concerned, on its conductivity. Generally speaking, the darker the colour of the soil the warmer it will be, because it absorbs heat, while a light-coloured soil partially reflects it. Humous matter is very useful in increasing the power of the soil to absorb heat, because of its dark colour. The power of retaining heat also varies, being greatest in the case of sand, and least in humus.

The presence of large stones on the surface of the soil affects its properties to some extent, by preventing evaporation and the radiation of heat. The soil is therefore warmer and moister, and in some cases it is found that removing the stones from the land diminishes its value very seriously.

CHAPTER IV

PLANT FOOD IN THE SOIL

THE chemical composition of soils varies enormously in the proportions of the different substances present, but there are a number of substances which are found in all fertile soils. The most important of these are :—

Organic matter.	Potash.
Silicious matter.	Soda.
Alumina, in clay.	Phosphoric acid.
Carbonate of lime.	Sulphuric acid.
Magnesia.	Chlorine.

Oxide of iron.

Organic matter may vary in quantity from 2 per cent or less in arable soils up to 98 per cent in peat. Alumina, from less than 1 per cent in sandy land to 10 or 11 per cent in clay soils, occasionally rising to as much as 13 or 14.

Silicious matter varies from about 1 per cent or less in peat soils to 90 per cent or more in poor sand. Silica exists partly in a soluble condition, but most of it is insoluble. In fertile soils the quantity of soluble silica is greatest, while in sandy land there may be none.

Carbonate of lime varies from less than 1 per cent up to 80 or 90 per cent in limestone soils. A fair proportion is from 4 to 5 per cent.

Magnesia usually occurs in quantities ranging from a mere trace up to 0·5 per cent, though sometimes it exists in larger quantities.

Potash, from a mere trace in sandy or peaty soils to 1·5 in some clays.

Soda also occurs in very small quantities, usually forming less than 0·5 per cent of the soil.

Phosphoric acid generally makes up less than 0·25 per

cent, though in alluvial soils a much larger percentage is sometimes found. Sulphuric acid occurs in very small proportions, usually being combined with lime. Chlorine is also unimportant, and exists usually in combination with sodium. Oxide of iron varies in quantity from 3 to 5 per cent, but in extreme cases the variation may be from 1 up to 12 per cent. The percentages stated above are of course only general figures, and in extreme cases variation may take place beyond these limits. The *composition of four soils* is given in the following table:—

TABLE I.

Percentage Composition of Soils.

	I.	II.	III.	IV.
Silicious matter	96·40	78·35	88·05	0·405
Alumina	} 1·81	1·74	2·42	} 0·536
Oxide of iron		5·34	3·52	
Lime	0·20	3·27	0·86	0·479
Magnesia	0·10	0·37	0·47	0·144
Potash	0·24	0·30	0·33	0·131
Chloride of sodium	...	0·94	1·08	{ soda 0·065 }
Sulphuric acid	0·13	0·07	0·03	0·051
Phosphoric acid	0·04	0·28	0·09	0·053
Carbonic acid	traces	1·98	0·69	0·376
Organic matter *	1·08	7·36	2·46	97·769
*Containing nitrogen	...	0·28	0·11	1·428
Equal *to ammonia*	...	0·34	0·13	1·734

No. 1 is described as "a poor sandy soil," and the amount of silicious matter in it is too great for agricultural purposes. No. 2 is a rich loam on the chalk formation. No. 3 is a strong loam, and No. 4 a peat soil. The first and last of these are rather exceptional in composition, but serve to illustrate the general character of sandy and peaty soils respectively.

It may generally be observed in the composition of soils that the amount of potash present bears some relation to the amount of clay. This is accounted for by the fact that clay is often formed from rocks containing a good deal of potash, some of which remains after their disintegration.

Similarly, the nitrogen varies to some extent with the amount of organic matter in the soil, though it does not as a rule form any definite proportion of it. Commonly, the larger the amount of organic matter in the soil the smaller the percentage of nitrogen contained in that organic matter.

It has been shown in the foregoing chapters that soils are formed, more or less directly, from rocks, and it therefore follows that, to some extent at least, they will vary in composition and properties with the rocks from which they are formed. The soil will, however, differ from the rock in its composition, because, in the process of weathering, the more soluble constituents of the rock will be washed away, and sometimes part of the finer material formed in the process of weathering will also be carried away mechanically, so that the soil left will consist principally of the least soluble parts of the rock. The following table gives a good example of this process of formation, showing the composition of the rocks, basalt and greenstone, before and after weathering[1]:—

TABLE II.

Percentage Composition of Rocks in their Natural State and after Weathering.

	1. BASALT (Bohemia).		2. GREENSTONE (Cornwall).	
	Unaltered.	Altered.	Unaltered.	Altered.
Silica	44·4	42·5	51·4	44·5
Alumina	12·2	17·9	15·8	22·1
Lime	11·3	2·5	5·7	1·4
Magnesia	9·1	3·3	2·8	2·7
Potash	0·8 }	0·2	1·6	1·2
Soda	2·7 }		3·9	1·7
Iron-protoxide	12·1	...	12·9	...
Iron-peroxide	3·5	11·5	2·5 }	17·6
Manganese-oxide	...	...	0·5 }	
Titanic acid	trace	1·2	0·7	1·0
Water	4·4	20·4	1·7	8·6
	100·5	99·5	99·5	100·8

[1] Prestwich, *Geology*, vol. i. p. 53.

In both these cases the alumina is very little affected by the process of weathering, while all the other constituents are more or less reduced in quantity. The extent of this loss is shown by the following figures, in which the amount of silica, lime, etc., per 100 parts of alumina present is shown before and after weathering in each case :—

TABLE III.

Composition of Rocks containing 100 parts of Alumina.

	BASALT.		GREENSTONE.	
	Unaltered.	Altered.	Unaltered.	Altered.
Alumina . . .	100	100	100	100
Silica	364	237	325	201
Lime	93	14	36	6
Magnesia . . .	76	19	17	12
Potash . . .	6	1	33	13
Soda . . .	22			
Iron-protoxide . .	99	...	106	
Iron-peroxide . .	29	64		79
Maganese-oxide . .	...	...	3	
Water . . .	36	114	11	38
	825	549	631	449

Many of the substances required by the plant occur in the soil in such a form as to be of no direct use for plant food, because they are insoluble; they must be dissolved before the plant can take them up. Accordingly, the plant food in the soil may be divided into two classes :—

1. Available plant food.
2. Dormant plant food.

Table IV. shows the amount of soluble and insoluble matter in a strong loam, and illustrates the difference between these two classes of useful substances. In this case about 0·67 per cent of the mineral matter is soluble in water :—

TABLE IV.

Percentage of Soluble and Insoluble Matter in a Strong Loam.

Mineral Matter.	Soluble in Water. Readily.	Soluble in Water. Sparingly.	Insoluble in Water.
Potash	0·0749	...	1·1225
Soda	0·0172	...	0·4876
Chlorine	0·0831	...	...
Magnesia	0·0194	...	0·3284
Oxide of iron	...	...	3·3822
Phosphoric acid	...	...	0·3760
Sulphuric acid	...	0·1688	...
Silicious matter	...	0·0292	73·4153
Lime	...	0·2026	1·1199
Alumina	...	...	8·4828
	0·1946	0·4006	88·7147
Organic matter	10·6913		

The insoluble matter of soils is always being acted upon by a weathering process, similar to that which goes on in the formation of soils. Cultivation of the soil assists this action by exposing the soil to the air, so that we find that dormant plant food becomes available most rapidly in arable land. The value of tillage in this respect has long been recognised, for Jethro Tull, writing in the eighteenth century, laid it down as a general principle that tillage will supply the place of manure.

The Weedon system of wheat-growing, which was advocated in 1849, depended upon the same fact. Under it wheat was grown in narrow strips with spaces of the same width between. These spaces were fallowed and worked during the growth of the crop, and each year wheat was grown on the land which was fallowed in the previous season. In this way very large crops were obtained in some cases; but as the success of the system depended on the amount of plant food in the soil, and the rate at which it became available, it was not applicable to all circumstances.

One valuable effect of exposing the soil thoroughly to the air is that the organic matter is oxidised, so that the carbon is given off in the form of carbon dioxide. The nitrogen contained in humus is not available for the plant's use until it has been converted into nitric acid, and this takes place during the process of oxidation. The change is brought about through the agency of bacteria, which, besides oxidising the carbon and producing carbon dioxide, convert the nitrogen, first into ammonia, and afterwards to nitric acid. These nitrifying organisms are present in enormous numbers in all fertile soils, and, wherever the conditions are favourable, prepare plant food in the way described. The conditions required in the soil are—

1. Moisture.
2. Air.
3. Suitable temperature.
4. The presence of a base—that is, a substance with which the acid may combine when formed.

In the presence of any considerable quantity of either acid or alkali the nitrifying organisms cease their action, so that the presence of a base to combine with the nitric acid *produced is necessary for the continuous action of the* bacteria.

Want of exposure of the soil to the air and consequent imperfect oxidation is also injurious by producing acidity. For example, if the soil be undrained and water-logged, the water excludes the air, and prevents thorough oxidation. The humus, decomposing partially under such conditions, produces various organic acids, which cause sourness of the soil and make healthy plant growth impossible. Such a condition is often seen, especially in the case of wet pastures on clay soils.

CHAPTER V

THE SOIL'S LOSSES AND GAINS

When dormant plant food has become available, or when any soluble manure has been added to the soil, the question arises, What becomes of that part of it which is not at once utilised by the crop? It is of course well known that some soils have the power of holding manure, and retaining it for a considerable time, while others, on the other hand, are termed "hungry" soils, and require immediate manuring for each crop grown. This difference in the "absorptive power" of the soil, as it is called, is of very great importance to the farmer, and must be understood in order to utilise the plant food present in the most economical way. The various soluble substances are retained by the soil to a slight extent mechanically, but this action is comparatively unimportant, and any material held in this manner is liable to be washed away by rain. The retention of soluble plant food is principally owing to the fact that the elements enter into chemical combination with various substances found in the soil, the chief of which are hydrated silicates, hydrate of alumina, ferric oxide, and humus. In this way potash, phosphoric acid, ammonia, and some other soluble substances are retained, especially in those soils which contain a moderate proportion of carbonate of lime. This last substance seems to assist the absorption of manurial substances by helping to decompose them, the lime combining with the acid of the manure, and the base of the manure remaining in the soil. For example, if sulphate of potash be added to a fertile soil containing lime, the potash is retained in the soil, and the lime combines with the sulphuric acid, which previously

existed in the sulphate of potash, forming sulphate of lime.

It has been ascertained that the water draining from fertile soil rarely contains any potash, phosphoric acid, or ammonia, but it usually contains a certain amount of nitric acid, and it has been found that soils have no power of retaining nitric acid or nitrates except mechanically. This is an important fact, because it has been shown that nitric acid is always being formed in the soil when the conditions are favourable, and it therefore follows that nitrogen in the soil is always liable to be washed away in the form of nitrate, in whatever form it might have been to commence with. This waste of nitrogen in the drainage water is found to depend more on the rate of rainfall than on its quantity, a very heavy fall lasting for a short time washing away the nitrates to a greater extent than the same quantity of rain spread over a longer period.

The loss of nitrogen by drainage is partially counterbalanced by a gain in nitrogen brought down to the soil by rain. This nitrogen exists in the form of organic matter, ammonia, nitrates, and nitrites. The quantity of nitrogen brought down in the rain is relatively greater in summer than in winter, and exists in smaller proportion in rain water if the fall be abundant than if slight.

Table V. shows the results obtained by Lawes and Gilbert at Rothamsted, divided according to the season and the abundance of rainfall, the figures in every case being given in parts per million of rain[1]:—

[1] Lawes and Gilbert, *Journ. R.A.S.E.*, vol. xvii. S.S

TABLE V.

The Composition of Rain Water in relation to the Amount of Rainfall and Season of the Year.

PARTS PER MILLION.

Quantity of Rainfall.	Total Solid Matter.	Carbon in Organic Matter.	Nitrogen as Organic Matter.	Nitrogen as Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Nitrogen.
IN THE WHOLE YEAR.						
Below ·10 inch	38·2	0·95	0·21	0·46	0·12	0·79
From ·10 to ·20 inch	36·9	1·19	0·23	0·44	0·17	0·84
From ·20 to ·40 inch	34·9	0·74	0·14	0·23	0·11	0·48
From ·50 to ·90 inch	21·5	0·71	0·12	0·26	0·18	0·56
IN THE SUMMER MONTHS, APRIL TO SEPTEMBER.						
Below ·10 inch	42·2	1·10	0·17	0·48	0·17	0·82
From ·10 to ·20 inch	41·9	1·18	0·18	0·43	0·18	0·79
From ·20 to ·40 inch	42·6	1·01	0·15	0·25	0·12	0·52
From ·50 to ·90 inch	26·3	0·97	0·11	0·35	0·38	0·84
IN THE WINTER MONTHS, OCTOBER TO MARCH.						
Below ·10 inch	35·0	0·83	0·25	0·44	0·10	0·79
From ·10 to ·20 inch	25·1	1·22	0·33	0·48	0·16	0·97
From ·20 to ·40 inch	21·6	0·39	0·13	0·20	0·09	0·42
From ·50 to ·90 inch	15·1	0·37	0·14	0·14	0·08	0·36

In these experiments it was found that the proportion of organic matter was greater in summer than in winter, but that the organic matter contained relatively less nitrogen in summer.

Nitrogen also exists to some extent in dew and hoar-frost, occurring generally in larger proportion than in rain water. Table VI. shows the proportion of parts per million of nitrogen in various forms occurring in dew and hoar-frost collected at Rothamsted :—

Table VI.

The Maximum, Minimum, and Mean Amounts of certain Constituents in seven Samples of Dew and Hoar-frost, in Parts per Million.

	Total Solid Matter.	Carbon in Organic Matter.	Nitrogen as			
			Organic Matter.	Ammonia.	Nitrates and Nitrites.	Total Nitrogen.
Highest Proportion	80·0	4·50	1·96	2·31	0·50	4·55
Lowest Proportion	26·4	1·95	0·26	1·07	0·28	1·66
Mean, 7 samples	48·7	2·64	0·76	1·63	0·40[1]	2·79

[1] Mean of four analyses.

Soils, according to Berthelot, appear to have the power of absorbing nitrogen from the air, forming compounds of an albuminoid character. This power depends chiefly upon the amount of humus and clay in the soil, principally on the former. Berthelot found, in the case of a soil growing no crop when freely exposed, that in a depth of 18 centimetres an amount of nitrogen was absorbed, varying from 30 kilogrammes per hectare to 150 kilogrammes in eleven weeks, an amount equal to from 27 to 135 lbs. per acre. This absorption of nitrogen is facilitated by tillage, and is one of the great advantages of bare fallowing.

Another way in which the soil gains nitrogen is through the medium of the leguminous crops, such as clover, peas, beans, lupines, etc. It has long been known that the growth of these plants enriches the soil in nitrogen, by the root and leaf residue left after the crop is removed; but the source whence this nitrogen was derived was not understood. Comparatively recently it was found by Hellriegel, in a

series of experiments in which plants were grown without any supply of combined nitrogen, that free growth and development only takes place in leguminous plants when their roots bear small nodules or tubercles, which examination shows to contain nitrogen fixing organisms, and to be caused by their presence. When a leguminous plant is grown from seed on sterilised nitrogen free soil, no root tubercles are produced, and growth only takes place to an extent regulated by the amount of nitrogen originally contained in the seed. When the nitrogen fixing organisms are introduced, as, for example, by watering with a watery extract of a fertile soil on which a similar leguminous crop has been grown, tubercles are formed, and free growth takes place, provided the soil contains a sufficient supply of non-nitrogenous plant food. This results from the power of the organisms to utilise the nitrogen of the air, which is otherwise not directly useful for plant growth, and to form compounds which can be made use of by the leguminous plant.

It has been shown, however, that the organism existing in the root nodules of clovers and many other plants is not able to benefit lupines and one or two other crops of similar habit, no effect being produced by the "seeding" of soil in which lupines are growing with an extract of a soil producing clover; but when seeded with an extract of a soil in which lupines had grown freely, nodules were produced, and luxuriant growth took place.

Several substances useful to plants besides nitrogen are also brought down to the soil in rain water. Chlorine is perhaps the most important of these, and it is found in rain water in large quantities in the form of chlorides of various elements. The amount of chlorine thus added to the soil in a year depends on the locality, being chiefly influenced by proximity to the sea, and by the prevailing wind. For instance, at Cirencester, the chlorides in the rain water are equal on the average to about 35 lbs. of common salt per acre per annum, while at Rothamsted the average quantity is only equal to 24 lbs. per acre. The quantity varies also with the season, being greatest in winter, and, as in the case of nitrogen, is in smallest proportion in rain water collected during heavy falls, unless this be accompanied by a strong wind from the sea.

CHAPTER VI

BRITISH GEOLOGICAL FORMATIONS AND THE AGRICULTURAL CHARACTERISTICS

As the composition of the soil depends on that of the rock from which it is formed, we find that, as regards sedentary soils, the agricultural properties of the different districts of the country vary according to the geological formation occurring in them. The geologist divides all rocks into two main groups:—

1. Igneous rocks.
2. Aqueous rocks.

The igneous rocks are those which have been formed under the influence of great heat, and in many cases deposited in their present position in a state of fusion. They occur in no special order, and indeed have been formed at almost all geological periods. The aqueous rocks, on the other hand, are those which have been deposited from solution or suspension in water, and they are therefore often called "sedimentary." Having been laid down in this way from water, the process has been a gradual one, and they lie in distinct layers or strata, which are placed in more or less regular order, the oldest rocks being the lowest of the series. This regularity of stratification of the various beds is the readiest means of distinguishing the aqueous from the igneous rocks. A list of the aqueous rocks found in this country, with particulars of their formation, is given in the following table:—

TABLE VII.

British Formations.[1]

		Recent	Alluvia, peat, and estuarine beds now forming, etc.	
		Post-tertiary	River and estuarine alluvia, and some peats. Latest traces of British glaciers. Great glacier moraines, and boulder clays with marine and freshwater interstratifications. Forest bed of Norfolk, Chillesford beds, and	
Tertiary, or Cainzoic, and Post-tertiary.	Upper	Newer Pliocene	Norwich crag, with land mammalia, etc.	
		Older Pliocene	Red crag. Coralline crag.	
	Middle	Miocene	Bovey Tracey and Mull beds, with igneous rocks.	
	Lower	Upper Eocene	Hempstead beds. Bembridge beds. Osborne beds. Headon beds	Freshwater river beds, with marine interstratification.
		Middle Eocene	Bracklesham and Bagshot beds	Marine.
		Lower Eocene	London clay. Marine. Woolwich and Reading beds and Thanet sand. Freshwater, estuarine, and marine	

[1] Ramsay, *Physical Geology and Geography.*

Secondary, or Mesozoic.	Cretaceous	Chalk; Upper greensand; Gault; Lower greensand; Atherfield clay		Marine.
	Wealden Series	Weald clay and Hastings sands; Purbeck beds		Freshwater river beds, estuarine and lagoon beds, with marine interstratifications.
	Oolitic Series	Portland oolite and sand; Kimeridge clay	Upper	Marine in middle and south of England. Between the inferior oolite and great oolite, partly fresh-water and terrestrial, *in Northamptonshire, Lincolnshire, and Yorkshire.*
		Coral rag; Oxford clay	Middle	
		Cornbrash; Forest marble; Bath or great oolite; Stonesfield slate; Inferior oolite and sand	Lower	
	Lias	Upper lias clay; Marlstone (middle lias); Lower lias clay and limestone; Rhætic beds. Passage beds		
	Triassic	Upper. New red marl (Keuper). Salt lake. Lower. New red sandstone (Bunter). Lake *deposits, probably* salt, but *perhaps partly* fresh or brackish.		
Primary, Palæozoic.	Permian	Magnesian limestone; Rothliegende		Salt lakes.
	Carboniferous	Coal measures and millstone grit. Partly terrestrial, freshwater and marine. Carboniferous limestone and shales. Chiefly marine, and in north of England, and Scotland, partly terrestrial and freshwater.		
	Old Red Sandstone and Devonian	Upper; Lower		Freshwater lakes. Devonian marine.
	Silurian	Upper Silurian; Lower Silurian		Marine.
		and Cambrian. Probably marine and fresh-water beds interstratified.		
	Laurentian	Marine.		

From an agricultural point of view the aqueous rocks are of far greater importance than the igneous, but many of the formations mentioned in the above table occupy comparatively little of the surface of the country, and therefore

need not be noticed at any great length. In the following description of the different formations the most recent are dealt with first.

The alluvial deposits, which have been formed comparatively lately, and indeed are to some extent being formed at the present day, are found in greatest development in East Yorkshire, Lincolnshire, and about the Wash. They also are of some agricultural importance on the coasts of Essex, Somerset, and Lancashire. It may be noticed, however, that on a small scale these soils may be found in almost any river valley, often forming very valuable land. The composition and texture of the soil varies very much, according to its origin and method of formation. In some cases it consists of peaty material containing very large quantities of organic matter; in others sand is its chief constituent, and one finds a light "silty" soil; while sometimes, again, they form heavy clays. In the true fen districts, where, as a rule, the soil is rich in organic matter, most crops grow rather rank in character, and, generally speaking, do not yield quite so well as would be expected from their appearance. This is perhaps particularly the case with corn crops. A characteristic of the farming of the district is the growth of brown or black mustard and rape for seed, and the latter crop is also very much cultivated for feeding purposes in place of part of the ordinary root crop.

The drift soils formed by glacier action also vary very much both in character and in the way they are deposited. Commonly, their general character is that of a stiff clay, often mixed with stones. Taking, as an example, the boulder clay already mentioned, the soil is naturally a poor one, but by judicious management, and particularly where it is mixed with other kinds of soil, it may be transformed into useful fertile land. It is particularly seen in Norfolk and Suffolk, where to some extent it is chalky in character, and yields excellent soil for arable farming.

Of the tertiary formations the most important is the Eocene, which lies for the most part near London, though a good deal of it is covered by sand or gravel. The different beds of the Eocene vary very much, but most of the surface is cultivated, this being rendered possible owing to the

convenience of the London market for the sale of produce. In one or two cases, however, as, for example, in the Bagshot sand, the soil is of so poor a character as to be practically worthless for agricultural purposes. The London clay, which is a most important member of the Eocene series, produces a soil of a brown colour, and of a very heavy, retentive nature. In its natural condition it is of very slight value, when drained it produces good crops of wheat and beans, but generally it is too heavy for the ordinary root crops. Special crops are, however, grown for sale in the London market, such as cabbages and other plants of the kind, and market gardening is followed in a part of the district nearest London. Very great improvement may be effected by the use of lime, and of town manure, the latter particularly being used in very great quantity. In the parts of the formation farthest from London, a good deal of the surface is occupied by grass land, often of good quality, and a good deal of hay produced from this is sold into London. Another series of Eocene beds occurs in the south of Hampshire, and consists of very poor sands, which produce a soil only suited for the growth of heather and sometimes pine trees, with occasional beds of wet, cold clay of very small agricultural value. The greater part of this district is occupied by the New Forest.

Passing on to the secondary rocks we find, first, the Chalk. This occupies the surface of the country in a continuous band running from the north-east coast of Norfolk in a southerly and south-westerly direction to the coast of Dorsetshire, thence turning east and forming two branches, running to the Isle of Thanet and Beachy Head respectively. It is also important in Yorkshire and Lincolnshire. The general character of the district is undulating, and of the kind usually described as down-land. For instance, the North and South Downs, Salisbury Plain and the Wolds, are all examples of this formation. The natural produce of the soil is a short, rather wiry grass, which, however, is very well suited for sheep. Where the surface is not too steep a good deal of it has been broken up and is under cultivation, but much of it is too high-lying and exposed for profitable arable farming. In any case the crops produced are usually light, though often of good quality. One of the

greatest drawbacks to the soils of this formation is their extremely dry and non-retentive character, so that they suffer very much from drought, and the water supply is rather precarious, even water for drinking purposes having in many cases to be obtained from ponds and artificial streams. The lower beds of the chalk formation are, generally speaking, of a darker colour than the upper, and are less liable to suffer from drought. In certain districts the chalk is covered with a rather stiff, cold clay soil, as, for example, in Wiltshire; and in other instances, as in Sussex and the adjoining counties, it is overlaid with drift.

Next to the chalk is the Greensand, which consists of a group of three beds, namely, the Upper Greensand, the Gault, and the Lower Greensand. These run parallel with the chalk from the coast of Yorkshire to that of Dorsetshire, coming to the surface on the west side of that formation. They also occur next the chalk, south of the North Downs and north of the South Downs.

The Upper Greensand consists of a rather calcareous sand—that is, a sand containing lime—and the soil formed is generally dry and porous. It is fairly fertile, producing crops of good quality, though often rather light; but in some places the soil is shallow, and there of course the crops are inferior. The soils of this formation are well suited for hop-growing, and produce some of the best hops in the market.

The Gault is not of much agricultural importance, as it occupies a comparatively small amount of the surface. It consists of a blue clay, which on weathering produces a brownish soil of a very cold and sticky character. With drainage, however, it may be converted into useful arable land, though it is always difficult to work. A good deal of the formation is laid down to grass, most of which is poor and wet.

The soils of the Lower Greensand are loams and sands of a very variable character, often changing from a fertile soil to a poor one within one field. The soil usually contains a great deal of iron, often so much as to render the land absolutely barren.

The Weald clay occurs in the district from which it takes its name, in Kent, Sussex, and Surrey, lying next to

the lower greensand. The soils produced from it are of a stiff character, and yellowish in colour. Usually they are very wet and poor, but sometimes loams occur which are very productive, and are largely employed for the growth of hops and fruit.

The Hastings beds are found next to the Weald clay, and almost surrounded by it. They produce soils which are generally of a sandy character, and poor and hungry. The country is usually higher above the sea than the Weald clay, and is undulating in character. Much of the surface is occupied by forest and waste land. A few beds of clay occur, however, in this formation, which formerly produced the ore when iron smelting was carried on in the Weald district.

The Oolitic series of beds, which occurs next, consists principally of limestone, with some rather important strata of clay. It forms a broad band running from the coast of Yorkshire to the coast of Dorsetshire, lying next to and parallel with the cretaceous formation. The greatest development of the series is found in the Cotswold district, where a very wide stretch of country consists entirely of oolitic limestone.

The Portland beds and Coral Rag may be considered together, for their agricultural properties are very similar. The soil produced is very thin, and calcareous in composition. Occasionally, however, rather rich sandy loams are found, but this is the exception. Most of the soils of this formation are cultivated as arable, and are devoted principally to the growth of corn and to sheep farming. Some grass land is, however, found, which when dry is very poor and benty, and when wet is practically worthless.

The Kimeridge Clay, which lies between the Portland beds and the Coral Rag, is a stiff, grayish clay, very similar in its characteristics to the gault. It is very difficult to work as arable land, and consequently much of it is laid down in pasture, which is often of first-rate quality.

The Oxford Clay is again very similar, very stubborn to work, but is acted upon to a remarkable extent by frost, so much so that wheat and other autumn-sown crops have often so little roothold in the spring as to suffer severely. A good deal of the surface is in grass, some of which is very

valuable; but much of it is poor and cold. Both this formation and the Kimeridge are farmed to a great extent for the production of milk, chiefly for milk-selling and cheese-making.

The Cornbrash forms calcareous soils, principally suited for corn-growing, especially for barley, the quality of the produce, however, being more remarkable than the quantity.

The Forest Marble forms rather retentive soils, though still distinctly calcareous in composition. Good corn crops may generally be grown, except where the soil is very shallow or "brashy" in texture. Where the rock is thin bedded stone-tiles are obtained, which are largely used in the district for roofing purposes.

The Great Oolite and Inferior Oolite usually produce light marls, which are often very brashy. They vary, however, to a considerable extent, occasionally being of a heavy, retentive nature, though in this case, as with the Oxford clay, the frost acts strongly upon them and assists cultivation. The land generally is of a reddish colour, especially on the inferior oolite, so that it is sometimes locally called "red land." The high-lying parts of the Cotswold district rest on these two formations, and consist of bare undulating hills, steep-sided, and with rather fertile valleys intersecting them. The great oolite yields the famous Bath stone, and the inferior oolite often produces stone useful for rough work, such as walling.

Following the oolitic series is the Lias, which forms another more or less continuous band from Yorkshire to Dorset. The soils resting upon it are chiefly clays, but on the beds of the middle lias, marl, often containing sand, is found. The clays are chiefly laid down to grass, though when cultivated judiciously as arable they form good wheat soils. The lighter soils of the formation are very useful for arable purposes.

The New Red Marl and New Red Sandstone of the Trias formation lie parallel to the oolite and lias, running from the Tees to the coast of Devonshire. They occupy the greatest amount of surface in the Midlands, and extend from that district into Cheshire and Lancashire. Though the trias forms such a large proportion of the rock of the country, yet it is overlaid to a great extent with drift, so

that much of it does not influence the agriculture of the country. The materials of the formation form useful arable soils, and in some cases very valuable pasture is situated on them. The sandstones produce very good loams, which, however, are sometimes too porous to yield large crops. The best of the loams are celebrated for the growth of fruit, as in Worcestershire, and to some extent for the growth of hops.

The primary rocks are as a rule hard and compact, and consequently weather slowly, thus giving a wild character to the scenery of the country, and making it of little value from an agricultural point of view. There are, however, exceptions, which will be noticed in dealing with these rocks in detail.

The Permian formation consists of magnesian limestone and red sandstone. The magnesian limestones occur chiefly in a band running almost straight from the mouth of the Tyne to Nottingham. The soil generally is light and dry, chiefly cultivated as arable, and generally fertile. Occasional beds of clay occur, which are largely devoted to pasture. The red sandstones present their greatest development in the valley of the Eden and about the Solway Firth. The soil is generally a free-working loam, which gives a large yield of most of the ordinary farm crops.

Passing on to the carboniferous rocks, we find first the Coal Measures, which occur principally in Northumberland, Durham, Yorkshire, Derbyshire, Lancashire, and South Wales. These rocks consist largely of beds of shale and sandstone, the former of which produce heavy cold clays, resting on a yellow clay subsoil, the latter producing hungry light soils. Where the two beds of soil are mingled, good arable soils are produced, and the sandy land, where cultivated at all, is chiefly arable. The clays are principally in grass, which, though often poor, is occasionally of very good quality. A great difficulty prevails in the coal districts, namely, that of obtaining sufficient labour: for the comparatively high wages and short hours of work prevailing in the coal-pits tempt men away from agricultural work. This forms an additional reason for so much of the land being in grass.

The Millstone Grit, which occurs next the coal measures, is found principally in a broad band passing south from

Northumberland into Lancashire and through Yorkshire, forming the high-lying wild country of the Pennine Chain. It is also found to some extent in Devonshire. This is a very hard, slow weathering rock, producing thin soils of a very poor and hungry character. This, and the altitude at which the greater part of the formation occurs, render the land almost useless for agricultural purposes, and in consequence much is occupied by waste moorland.

The Carboniferous or Mountain Limestone occurs in greatest quantity in Northumberland and Cumberland, and to a less extent in Yorkshire, Derbyshire, and the Bristol district. It consists of a bluish limestone, with thin beds of sandstone. As a rule the formation stands high, and forms rather flat-topped terraced hills, covered with thin soils, which produce only thin sweet grass. In the valleys, where the soil is deeper, however, rich pasture is often found, some being good grazing land, and occasionally arable farming is also followed. Generally, the soil is naturally drained by cracks and fissures in the rock, but in the valleys artificial drainage is required. The lime obtained by burning the carboniferous limestone is perhaps the best for agricultural purposes.

Below the carboniferous limestone is the Carboniferous Shale, consisting of thin beds of shale and limestone, the soils from the former being similar to the clays of the coal measures, and those from the latter being like the mountain limestone soils.

The Old Red Sandstone or Devonian formations occur in Devonshire and on the borders of Wales. The soil is generally red in colour, but is very variable in composition. Some consist of a light sharp sand, generally lying at a considerable elevation, and of little value. Where lime and clay occur mixed with the sand, as in Herefordshire, very rich soils are produced, forming good arable and pasture, and being remarkable for the growth of fruit and hops.

The Silurian formation is divided into two groups of beds, the Upper and the Lower. The Upper Silurian occurs on the borders of Wales and in the Lake district. It consists principally of shales, which produce cold clay soils, sandstones and limestones also being found, and being cultivated generally as arable. A great part of the formation is at too

great an elevation to be of much agricultural value. The *Lower Silurian*, which *occupies a large part of the surface of* Wales, and also occurs in Cumberland and Westmoreland, consists largely of sandstones, which produce an almost barren soil, generally occupied by moorland, with occasionally limestones and marls, which yield fairly good arable soils. The value of these latter is often diminished by the steepness and barren character of the country. On the grass land dairy-farming is carried on to a considerable extent.

The Cambrian and Laurentian formations, which are the lowest and oldest of the aqueous rocks, are of very little importance agriculturally, as they occupy only small areas in Wales and in the north of Scotland. In general characteristics they resemble the Silurian, being generally at a great elevation, and the soils being poor. In the valleys, however, where the soil is deeper, rather good pasture is found.

The igneous rocks, though occupying a considerable area, are as a rule of small agricultural value, because the soil is generally thin, and much of it lies very high. In this case, again, though the soil is poor and unproductive on the hills, in the valleys small areas of very fertile land may often be found. This is especially the case in soils produced from the granite rocks.

A few general points may be noticed in connection with the soils of the various geological formations. The hard rocks generally weather slowly, and therefore stand very high, so that the land is not valuable for agricultural purposes. They also produce thin soils owing to their slowness of weathering, and this also diminishes their value. Soft rocks, on the other hand, are generally low-lying, and the country has an undulating character, while the soils are generally deep. The clay soils, it will have been noticed, are generally devoted to grass, owing to the difficulty of cultivation, and to the greater likelihood of crops on heavy lands suffering from wet seasons. The great expense of cultivating these soils has also had some influence, since the prices of agricultural produce have fallen so as to make the profits small. Light soils are usually devoted to arable farming, and, to a great extent, whether arable or grass, to sheep farming. It is also important to notice that where soils formed from two

formations are mingled, the land is almost always more fertile than where either soil occurs alone. One other point must be insisted upon, namely, that the geological formation of the rock from which the soil is formed is of less importance from an agricultural point of view than its lithological character—that is, whether it be limestone, sandstone, or clay.

CHAPTER VII

SIGNS OF FERTILITY—IMPROVEMENT OF SOILS

SOILS are fertile only when they contain all the substances required by the plant in such a condition that the plant can make use of them. Sterility, more or less complete, may be caused by a number of circumstances, the chief of which are—

1. The presence of something hurtful to vegetation, such as an excess of organic acids or of saline matters, especially common salt.
2. Deficiency in one or more constituents required by the living plant.
3. The presence of too large a proportion of some one ingredient, such as organic matter, sand, lime, or clay.
4. When the soil forms a thin layer resting on the bare rock.
5. When it forms a thin layer resting on an impervious subsoil, or on a subsoil containing something injurious to vegetation.
6. Bad drainage and defective aeration.
7. Exposure to a bad climate.

A few general characteristics of good and bad land may easily be recognised. If the soil of the district be of small value, the population will be very thin and scattered; there will be an absence of grazing cattle in the pastures, and the young cattle will be very poor, while the timber and hedges will be stunted in character. Particular weeds commonly grow on inferior soils in large quantities, such as the common daisy, rest-harrow, foxglove, yellow rattle, and quaking grass in grass land, and the slender foxtail and others in arable

land. A good fertile district is shown by well-grown timber and hedges, and the presence of thriving stock in the fields, while any weeds present will be strong in their growth, owing to the superior value of the soil. Heavy clays have generally few kinds of weeds, while sandy land produces a great many, though poor and weak in their growth, especially poppies, the blue-bottle, wall-barley, and bracken. Soils containing lime commonly produce knapweed, scabious, burnet, and wild parsnip, while loams, which, generally speaking, are the most useful soils for agricultural purposes, produce many strong weeds, particularly chickweed, groundsel, speedwell, goosefoot, and various members of the mustard family.

Strictly speaking, improvements to the soil are of two kinds, permanent improvements and temporary improvements. Permanent improvements are those which increase the permanent or natural fertility of the soil, while temporary improvements are those which add to the temporary fertility or condition of the soil due to previous manuring and management. It is important to distinguish clearly between the permanent and temporary fertility of the soil. If crops be grown for some time without the application of any manure to the soil their produce will diminish rapidly at first, but after a few years it will be found that the decrease of the produce will be much less rapid, until in time the produce will become almost constant. The rapid diminution of the crop at first is due to the exhaustion of the temporary fertility of the soil, while the comparatively slight decrease in later years is due to a diminution in the permanent fertility. A good example of this is furnished by the experiments carried out by Lawes and Gilbert at Rothamsted, in which wheat was grown on the same land for fifty years, part receiving no manure during the whole of that period. Before the experiment began, the land was reputed to produce rather less than 22 bushels of wheat per acre, when it was grown under the ordinary conditions of farm management, once in five years. The following table[1] shows how the produce diminished under the continual cropping without manure during the first forty years of the experiment:—

[1] Lawes and Gilbert, *Journal R.A.S.E.*, vol. xx. S.S. p. 426.

TABLE VIII.

Table showing the Produce of the permanently Unmanured Land, in average periods of Ten Years.

	Bushels of Dressed Corn per Acre.	Weight per Bushel.	Total Produce Corn and Straw in lbs.
Mean of 10 years, 1844-1853 .	$15\frac{3}{4}$	58·25	2711
Mean of 10 years, 1854-1863 .	$16\frac{1}{2}$	57·57	2728
Mean of 10 years, 1864-1873 .	$12\frac{3}{4}$	58·97	1924
Mean of 10 years, 1874-1883 .	$10\frac{1}{4}$	58·25	1614
Mean of 40 years .	14	58·26	2244

Though the character of the seasons, which were exceptionally favourable in the second period, and unfavourable in the fourth, somewhat obscures the point, it will be seen that the difference between the average produce under ordinary conditions, and the mean of the first ten years of experiment is considerably greater than between the means of the subsequent periods of the same duration, owing to the rapid exhaustion of the temporary fertility at first. Generally speaking, permanent improvements render available stores of plant food which already exist in the soil, and improve the physical texture of the soil. Temporary improvements, on the other hand, usually consist of the addition of something to the soil which is useful to the plant as food. The most important permanent improvements are drainage, irrigation, liming, marling, claying, and clay-burning, while temporary improvements include manuring and cultivation. It should, however, be noticed that no strict line of demarcation can be drawn between permanent and temporary fertility, or between the two classes of improvements which shade into one another by insensible gradations.

CHAPTER VIII

DRAINAGE

DRAINAGE is one of the most important improvements of the land that can be carried out. Without it, it is useless to attempt any other improvements, for in undrained land they cannot yield their full return. If a hole be dug in the soil it will usually be found that water is reached at a certain depth, and that apparently below a certain depth the soil is quite saturated. The line up to which the soil is saturated is called the "water-table" or water-level, and the depth of this varies according to the texture of the soil and subsoil, the contour of the surface of the land, its position, and the climate of the district. For instance, if the soil and subsoil be sandy or gravelly, any water falling upon it will rapidly sink in and percolate through it, and will therefore find its way rapidly into the nearest spring or stream, so that it is impossible in such a soil for the water-table to be very near the surface. In the same way, on hillsides or sloping land the water will tend to flow down the slope, and so will make the soil drier towards the top of the slope and the water-table there farther from the surface. On the other hand, if the land be low-lying and little above the level of a lake or stream, the soil will naturally be full of water, and the water-table will be very near the surface. The climate affects the position of the water-table merely according as it is wet or dry, for the greater the quantity of water that falls on the surface of the land, the higher the water-table will be, other things being equal.

The object of drainage is to carry away quickly the water which falls on the surface of the land, and so eventu-

ally to lower the water-table in the soil. The fact of drainage being required may be known by a number of signs, the chief of which are—

1. The snow takes long to melt, and will sometimes lie in patches for a long time after it has disappeared from drier land.
2. In ploughing, the furrow-slice turns up with a wet, shining surface, has a tendency to bake hard in drying, and only crumbles with difficulty, so that the subsequent cultivation of the soil is more troublesome.
3. Seed sown germinates very slowly.
4. The crops come up unevenly, and are liable to fail in patches.
5. Those crops which do not fail have a stunted, sickly appearance, and are usually of a light yellowish-green colour.
6. The plants and weeds which grow on the land naturally are distinctive. On arable land, amongst others, the silverweed (*Potentilla anserina*) and coltsfoot (*Tussilago farfara*), while on grass land various kinds of rushes, sedges, and the tussock grass (*Aira cæspitosa*) are symptomatic of wet land.

There are four systems of drainage more or less frequently employed :—

1. Deep or parallel drainage.
2. Surface drainage.
3. Sink-hole drainage.
4. Arterial drainage.

The first three of these concern the farmer; the last, except on a small scale, can be carried out only by public bodies, or at least by large landowners. We shall consider these systems in the above order.

Deep, parallel, or thorough Drainage.—This consists in the provision of a system of channels at some little depth below the surface of the land, more or less parallel to each other, so arranged as to draw the water off evenly from the whole area of the soil. At one time any drainage that was done was carried out in quite an unsystematic way, drains being put in just as they were required to lay dry any wet

spots of land. This was of course treating the symptoms of want of drainage, but no attempt was made to cure the underlying cause of those symptoms, until in 1835 Smith of Deanstone first devised a system of parallel drains. He employed rather shallow channels, placing them near one another, apparently following as closely as possible the ordinary open sheep drains that are continually used on hill pastures, and which will be spoken of later on. Soon afterwards Parkes commenced draining land with parallel channels of a considerable depth, and at a greater distance apart, and after a time this better plan was generally adopted. More recently opinion has greatly changed, so that once more rather shallow drains are considered better than very deep ones.

The chief points to which attention must be paid in connection with drainage are—

1. The arrangement of drains.
2. Depth.
3. Distance apart.
4. Fall.
5. Construction of the channels.
6. Capacity of the channels.
7. Execution of the work.

The Arrangement of Drains.—The general idea on which any drainage system is laid out is that a main drain is laid along the lowest levels of the area under consideration, and from this a number of small drains, called minor drains, are laid parallel to one another, so as to draw off the water evenly from the whole of the soil. A reference to Fig. 1 will explain this. The main A-B, running up the lowest level of the land to be drained, receives water from all the minor drains *a*, *b*, and *c*, which are arranged parallel as far as the slope of the land will allow. The channels C-D and E-F, however, also receive water from some of the minor drains *a* and *c*, and deliver it into the main. These are therefore called "sub-mains."

Depth of Drains.—The determination of the exact depth at which drains should be laid depends first of all upon the texture of the soil and subsoil. The more pervious the soil and subsoil are, the deeper the drains should be laid,

because in a pervious soil the water reaches the drains more easily and quickly than in a retentive one. If the soil be impervious and the drains be laid deep, the water, if it reaches them at all, will do so so slowly that they will be practically useless. Therefore in this case the drains must be shallow. It must, however, also be remembered that in draining the land we not only have to take care that the *water is removed quickly, but that it is not drained away too quickly*. It has already been stated that the soil

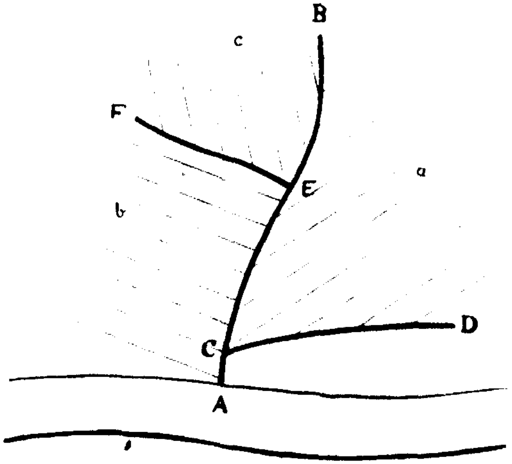

FIG. 1.—A-B, Main drain; C-D and E-F, Sub-mains; *a*, *b*, *c*, Minor drains.

receives valuable plant food from the air brought to it by the rain, and unless the rain water falling on the surface is compelled to pass through a sufficient depth of the soil, this plant food will be lost, and instead of being retained by the soil for the use of the plant, will merely be washed away in the drainage water. It will therefore be seen that we want the rain water to be filtered, as it were, before it reaches the drains. Clay soils have very great power of extracting plant food from the rain water, and consequently a comparatively small depth of a soil containing a large proportion of clay is sufficient to extract the whole of the useful

material from the water. Sand, on the other hand, has very little power of retaining such material, and consequently it is necessary, if the plant food is to be retained at all, that the water it contains shall be compelled to pass through a considerable depth of the soil. In the same way, when manure is applied to the surface, unless there is sufficient depth of soil above the drains, there is a risk of the manurial matter being washed rapidly through the soil, and being lost in the drainage water. Under ordinary circumstances of farming this is not very likely to occur, except in very light sandy soils.

Another point to be attended to with regard to the depth of drains is that they shall be deeper than the bulk of the roots of the ordinary farm crops. The following plants have been known to send their roots to the depths mentioned :—

TABLE IX.

Extreme Depth of Roots of Farm Crops.

Wheat	9	feet
Perennial grasses	4	,,
Cabbage	3	,,
White turnip	3	,,
Parsnip	13	,,
Saintoin	10	,,
Lucerne	10	,,

Grasses extend their roots to a considerable depth. M'Alpine gives the following as the average depth of root of some of the common grasses and clovers[1] :—

[1] *Trans. Highland and Agricultural Society*, 5th series, vol. ii.

TABLE X.

Length of Roots, of Grasses, and Clovers.

	Length of long roots.	Length of bulk of roots.
	Inches.	Inches.
Tall fescue . .	26	10
Cocksfoot .	24	10
Meadow fescue .	20	10
Timothy	16	6
Smooth-stalked meadow grass .	16	8
Perennial rye grass . . .	15	8
Italian rye grass . .	15	5
Red clover . . .	15	9
White clover . .	15	...
Sheep's fescue . . .	14	5
Wood meadow grass . .	14	6
Meadow foxtail . . .	14	7
Alsike clover	13	...
Rough-stalked meadow grass . .	...	6

In the case of arable land the disturbance of the soil by cultivation must be remembered in deciding on the depth of drains. The depth of the furrow in ploughing may be 10 inches. The sub-soiler may work 6 inches deeper than this, and at least 6 or 8 inches should be left as a margin for safety between the depth of cultivation and the top of the drain. In the case of large drains the diameter of the drain may be 6 inches or more, so that the minimum depth of such a drain in arable land would be about 2 feet 6 inches. Actually, such a depth is rather unsafe, particularly if steam tillage be employed, for if heavy engines pass over the land their weight is liable to displace and injure the drains unless they are laid at a greater depth than this.

The depth of a drain must also depend partly upon the depth of the soil and subsoil and the character of the underlying rock. For example, if a light soil, either humous or sandy, rests upon a bed of clay, it will usually be advantageous to cut completely through the porous layer,

and to lay the drain upon the clay or even imbedded in it. If this is not done there is great risk of the drain becoming displaced, owing to the shifting nature of the bed in which it is laid, and, moreover, the upper layer is more completely laid dry by this method. In the same way, where the position of the retentive and absorbent beds is reversed and a clay soil rests upon a porous rock, it is usually well to cut completely through the upper layer, so that the porous material beneath may help to carry away the water.

The depth of main drains depends entirely upon that of the minor drains, for it is essential that the latter shall deliver their water into the top of the mains, for if they deliver it at the side there is great risk of an accumulation of silt or earthy material either in the main or minor drain just above the junction.

Where there is no natural slope it is necessary for the depth to vary, gradually increasing towards the main, and in this way it is common to construct drains sloping gradually from a depth of 2½ feet at their upper end to about 5 feet at their lower end. The actual depths usually adopted in practice for the following varieties of soil are—

Stiff clay	2 ft. 6 in. to 3 ft.
Medium soils	3 ft. to 3 ft. 6 in.
Light soils	3 ft. 6 in. to 4 ft. 6 in.

But occasionally we find exceptions to the above, particularly in the case of very heavy and very light land, where the drains are made shallower or deeper according to circumstances.

Distance Apart.—The distance between the minor drains varies according to the soil and the depth. In a porous soil the drains can "draw" to a greater distance than in a retentive soil—that is, the water finds its way into them from a greater distance. The reason of this is obvious, for the water passes much more freely through a porous soil, and consequently acts more as though it were free and could flow as it does in a stream or lake. If it were free altogether, as in a lake, the water-table all through the soil would, of course, be at the level of the lowest drain; but the more impervious the soil the less is this the case, and the steeper will be the slope of the water-table up from each side of the drain. Thus in the case of heavy land, if the drains were put as far apart

as in the case of light land, there would be a considerable area not drained at all.

From this it will be seen that it is a matter of considerable importance that the drains should be near enough to each other, and an additional reason for this is afforded by the fact that when drains have been in action for a short time they open the soil and improve its texture, so that if close together they help one another, as it were, by facilitating the passage of water through the soil.

Usually there is a constant relation between the depth of a drain and the distance apart, and this, of course, will be readily understood from the fact already explained in reference to the slope of the water-table due to the impervious nature of the soil. Accordingly we find the following to be the usual proportion which the distance apart bears to the depth :—

In light soils	8 : 1 to 10 : 1
Medium soils	7 : 1 to 9 : 1
Heavy soils	5 : 1 to 7 : 1

Accordingly, taking into account the depths at which drains are made, we get the following as the average distances between the minor drains :—

Light soils	30 to 40 feet
Medium soils	20 to 30 ,,
Heavy soils	12 to 20 ,,

Before draining begins or the depth or distance apart of the drain is decided upon, it is a good plan to dig trial holes in order to ascertain accurately the character of the soil and subsoil, the water-level, and whether there are any water-bearing strata near the surface. The best way of employing trial holes is first to mark out on the surface of the land the direction of one of the future drains, and to dig trial holes at varying distances from this line; for instance, one hole 5 yards from the line of drain, one hole 10 yards, and one 15 yards, the actual distances depending on the probable requirements of the soil. The channel is then cut, and will, of course, lay dry those trial holes which are near enough to be affected by it. If in the above example the two trial holes nearest to the channel were laid dry, whilst

I

the third was not affected, or affected only slightly, it would show that a drain cut in that particular soil could act at least to a distance of 10 yards on each side, and consequently the distance apart of drains might be 20 yards. As this information will show to what extent the soil is porous, it will guide in determining the depth at which the drain should be made.

Fall of Drains.—This is very important in connection with the permanence of the drains, for unless the fall is sufficient the channels are very likely to become choked up by silt. The actual fall required will vary according to the kind of drain, because the better adapted the channel is for the flow of water the less is the fall required. In the case of large pipes having a smooth, even bore, the least fall allowable is about 1 in 200, but a considerably steeper one than this is desirable. The smaller the channel the greater the obstruction it presents to the flow of water, and the greater is the fall required to keep up the rate of flow which is essential to prevent a deposit being formed and the drain being choked. On the other hand, too rapid a flow is to be avoided, for if very swift the water is liable to displace the pipes or whatever material the drain is made of.

Construction of the Channels.—The method of constructing the channels of drains requires a great deal of attention, as upon the right choice of material depend the economy of construction and the efficiency of the drain when completed. At one time a great many different methods were employed, varying according to the district and the materials found immediately at hand; but latterly only one or two kinds of material have been employed to any great extent. The chief of these is the earthenware pipe or tile, the common form of which is merely a pipe, circular in section, and about 1 foot in length. A variety, elliptical in section, having a footing as shown in Fig. 2, is also used to some extent, the advantage it has over the round pipe being that with a smaller quantity of water passing through it the rate of flow is better kept up, and consequently there is less risk of a stoppage of the drain by silting up. An older form of earthenware drain was that called the horse-shoe drain, consisting of a tile in the shape of a horse-shoe (see Fig. 3); and perhaps rather

more common was the tile and sole drain (Fig. 4), consisting of a horse-shoe tile placed upon a flat sole. In this last form of drain it is important that the two kinds of tiles should break joint with one another—that is, that the joint of the horse-shoe tile should be placed upon the middle of the flat one.

With all these earthenware channels the quality of the tiles is of great importance. They should be made of a dense homogeneous clay containing a slight admixture of sand. If of pure clay, there is a tendency for the tiles to twist out of shape in the process of burning, and consequently such tiles are not economical to buy, owing to the large number which have to be discarded. On the other hand, if the proportion of sand be too great, the tiles

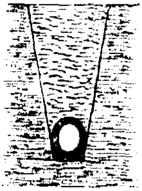

Fig. 2.

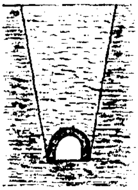

Fig. 3.

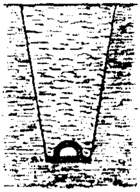

Fig. 4.

will be porous and liable to crumble and perish quickly. Similarly, if the clay contains more than a small proportion of lime it will be found that the tiles will crumble rapidly, particularly if exposed to the weather. The shape of the tiles is also important, and as far as the ordinary pipes are concerned they should be straight, of smooth and even bore, free from flaws, such as stones, etc., with straight-cut ends, not chipped or broken in any way. If the ends are not true, or if they be broken, it is impossible to fit the pipes closely together, and a larger space than is desirable is left, through which the soil will gain access to the pipe. Thoroughly good earthenware pipes should have clear resonance or "ring" when struck; if they sound quite dead they will rarely prove to be durable. There are several simple tests which may be employed for judging the quality of tiles. For instance, if a perfectly dry tile be stood on end in water, so

that about half its length projects above the surface, its porosity may be gauged from the height to which the water soaks up in the earthenware above the level of its surface in the vessel. Another way of testing the same point is to weigh a tile when dry, and then to soak it for a considerable time in water and weigh it again, when of course the gain in weight will represent the amount of water taken up by the tile. The gain in weight under these circumstances should not be more than about $\frac{1}{18}$ of the weight of the tile when dry. As a test of the durability of a tile when exposed to the weather, it is a good plan to soak it in water and dry rapidly before a hot fire. If this be done several times, unless the tile is of good quality, it will be found to crumble slightly on the surface. Another test of the same kind is to

A B

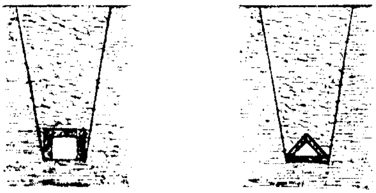

FIG. 5.

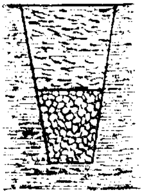

FIG. 6.

soak the tile in water and expose it to a night's frost, when, owing to the expansion of water in freezing, the tile will crumble to some extent unless it be of a durable nature.

In districts where thin-bedded flat stones can be obtained cheaply, stone drains are often employed, though not so commonly as formerly. There are several ways of constructing stone drains, two of which are shown in Fig. 5. Of these, B is better than A, because in the former there is a stone surface for the water to run upon, whereas in the latter the water runs on unprotected earth, and is very liable to wear it away and eventually to cause the sides to fall in. It must also be remembered that these drains are not so perfect in practice as one would expect, for as a matter of economy it is impossible to trim the stones so that they shall fit closely together, as shown in the diagram, and consequently there are large openings at intervals through

which the soil can find entrance and eventually impede the flow of water in the drain. A further drawback to stone drains as compared with the ordinary pipe drains is that they require a wider trench to be cut in constructing them, and consequently the cost of digging is greater.

Still more primitive is a method of making the channel for the water simply by cutting a trench and partially filling it with large rounded stones, filling in the soil above them. Fig. 6 shows the construction of such a drain. A similar plan, though a less permanent one, is to place three or more slender poles along the bottom of the trench after it is cut, when the spaces between them serve as a channel for the water. Such a plan is chiefly employed in the case of heavy clay land, and sometimes in peaty soils. In this latter the

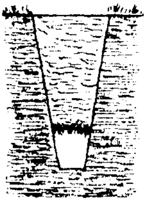

FIG. 7.

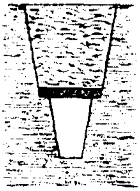

FIG. 8.

preservative properties of the peat make the drains more durable than under ordinary circumstances. Again, in some districts, where heavy clay is the prevailing soil, drains are made by placing faggots or even straw at the bottom of the trenches. These drains, particularly the latter, are of course of very little permanency.

Another class of channel is that made without using any other material than the soil itself, and naturally such drains are chiefly made in clay soils. The oldest form of these drains is perhaps the "wedge drain," which is made by first cutting the trench, taking care to remove the topmost layer as far as possible intact, then, when the channel is made of a proper depth and has been scooped out smooth, the upper layer of soil is first put into the trench and forced down as far as it will go. As will be seen in Fig. 7, a space is necessarily left below this wedge, and this space acts as the

channel for the water to flow in. Rather more durable than the wedge drain is the shoulder drain, in which the channel is cut as in Fig. 8, shoulders, as they are called, being left in the sides of the trench. On these shoulders the turf from the surface, if it be grass land, is placed across, the grass side downwards. If the land be under tillage, flat stones may be employed instead of turf, as shown in the figure, the soil being afterwards filled in in both cases level with the surface. Another plan for dispensing with tiles or stones is that known as "plug draining" or "block draining." This again is only applicable to heavy clay soils. The method of construction is as follows: A trench is cut of the size and depth required, and at the bottom is laid a block of wood, usually about 3 feet long or a little more, and 2 or 3 inches wide by 3 or 4 inches deep. Sometimes several short blocks connected together end to end are used instead of one long block. In either case clay is taken and carefully rammed down close about the block, after which the latter is drawn forward 2 or 3 feet and clay rammed about it again. In this way an open channel of tightly-rammed clay is formed in the soil at the required depth. It is usually objected to this system of drainage that the closely-worked clay will not allow the water to gain access to the channel; but this is not so to the extent that would be expected, because the clay is chiefly compressed at the top and sides of the channel, whereas water finds its way into drains in all cases from below. It is by the general rise in the level of the water in the soil that the drains begin to flow, and not by the direct flowing of water from the surface into them. This is a point of considerable importance, particularly in connection with the drainage of heavy clays, whatever system be adopted.

A channel very much like that made by plug draining may also be formed mechanically by "mole draining," which is carried out either by horse or steam power. In either case the operation consists essentially of drawing a conical piece of steel through the soil at the required depth, and thus leaving a rounded channel through which the water will afterwards flow. Usually, in order to finish the channel more perfectly and make its sides as smooth as possible, a cylinder of solid steel is attached loosely to the back of the

cone already mentioned, and this is technically known as the "mole." This form of drainage can only be used for comparatively small depths, 2 feet being the usual depth, though in special cases it may be as much as 3 feet. In consequence of this comparatively shallow working, mole drainage is most suitable for soils which are of a heavy, retentive nature, and free from rocks or large stones to the depth at which the implement works. The chief recommendation of mole drainage is its low cost, which varies, according to the manner in which it is carried out, from about 25s. to 40s. per acre. This, of course, makes it possible to employ it upon poor lands which could not be expected to give an adequate return on the cost of ordinary deep drainage. As to its durability it is said that on heavy clays mole drains will remain open for as much as twenty-five or thirty years. This, however, is probably somewhat above the average length of time during which they can be depended upon to act thoroughly.

In peat soils consisting almost entirely of vegetable matter it is difficult to construct drains so that they shall be permanent; they will probably sink, and so become displaced. To counteract this, therefore, the pipes, or sometimes horse-shoe tiles, are laid upon larch planks, by which means the tiles are supported and prevented from sinking, while the wood is preserved by the peat itself. Another plan sometimes adopted is to cut the peat into turves, of the section shown in Fig. 9, and after thoroughly drying them to place them face to face so as to form an open channel for the water in the manner shown. There is, of course, no tendency for these turves to sink in the peat, and the channels are said to keep open for upwards of thirty years.

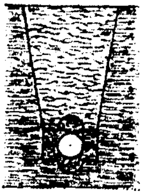

FIG. 9.

Another exceptional case is that of "running sand"—that is, sandy soil so full of water that it is not possible to obtain a firm bed for a drain. Where this occurs the only satisfactory plan is to use collared pipes, which are more stable than the ordinary drain tiles. Two forms of collared pipes are commonly employed, those having the collar attached to the pipe, and those having a loose collar fitting round ordinary tiles.

Capacity of the Pipes.—The diameter of the pipes used depends on the soil, depth of the drains, distance apart, and the rainfall of the district to be drained. The more sandy the soil is the greater the capacity of the drains must be, other things being equal, because sand has very little power of holding water, and consequently a heavy shower falling on the land sinks rapidly through it, and so causes a rush of water to flow through the drains almost at once. Clay, on the other hand, takes up a great deal of water, so that unless it be previously saturated, water falling on the surface will only find its way to the drains very slowly. The shallower the drains are the greater must be their capacity, because, the layer of soil above them being so much less, it has smaller capacity of retaining water when it falls upon it, so that the flow of water into and through the drains is naturally more rapid and more sudden. The distance of the drains apart influences the size required only because the closer the drains are placed to each other the more of them there are to a given area and consequently the smaller each individual channel may be. The greater the fall or inclination of the channel the more rapid will be the flow of water in it, and consequently the smaller the pipes may be to carry off the required quantity of water in a given time. It must not, however, be forgotten that for a given fall the velocity of the flow of water varies with the size of the pipe, there being less friction in proportion in large pipes than in small ones. The following table shows the velocity at which water flows through pipes of various sizes with various rates of fall:—

TABLE XI.

Discharge of Pipes in cubic feet per Minute.

Diameter of Pipe.	Fall.	
	1 in 100.	1 in 50.
1 inch	·47	·66
2 inches	2·67	3·77
2½ ,,	4·67	6·60
3 ,,	7·35	10·39
4 ,,	15·10	21·22
5 ,,	26·39	37·32
6 ,,	41·65	58·80

The influence of rainfall is naturally owing to the fact that the greater the rainfall the larger the quantity of water to be carried away, and consequently the larger the pipe that must be provided for the purpose. For purposes of drainage, however, it must be remembered that it is not so much the total rainfall in the course of the year that has to be considered as the rate at which the rain comes down--that is, the quantity which may fall in a short time. The following are stated to be the greatest rainfalls usually experienced in this country for the periods mentioned :—

TABLE XII.

Rates of Rainfall in various Times.

Length of Period.	Rate per Hour.
1 hour	1 inch
4 hours	0·5 ,,
24 hours	0·2 ,,

The actual rate of fall, however, varies very much with the district, and usually it may be considered that the greatest fall in twenty-four hours in lowland districts is about 3 inches, or rather less. It is not necessary, however, to make provision for carrying away the whole of this water, as a considerable proportion of the rain falling upon the land evaporates into the air, and so does not affect the drainage. The following table is given by Parkes to show the proportion of rain water carried from the land by drainage and that evaporated in the course of the years mentioned, the observations having been taken in Hertfordshire :—

TABLE XIII.

Percentages of Rain removed from Soil by Filtration and by Evaporation.

Totals of each Year.				
Years.	Rain.	Filtration.	Evaporation.	Rain, per acre.
	Inches.	Per cent.	Per cent.	Tons.
1836	31·00	56·9	43·1	3139
1837	21·10	32·9	67·1	2137
1838	23·13	37·0	63·0	2342
1839	31·28	47·6	52·4	3168
1840	21·44	38·2	61·8	2171
1841	32·10	44·2	55·8	3251
1842	26·43	44·4	55·6	2676
1843	26·47	36·0	64·0	2680
Mean	26·61	42·4	57·6	2695

The proportion of rain water removed by drainage varies considerably, according to the character of the surface on which it falls.

It has been stated by Professor Rankine that, on the average, the following proportion of the total rainfall is available—that is, is naturally removed by drainage (the total rainfall being taken as 1·0):—

TABLE XIV.

Proportion of Total Rainfall removed by Drainage.

Ground.	Available Rainfall.
Steep surfaces of granite, gneiss, or slate	nearly 1·0
Moorland and hilly pasture	from 0·8 to 0·6
Flat cultivated country	from 0·5 to 0·4
Chalk	0

And he further states that in the case of cultivated land it is only necessary to make provision for the drains to be able to discharge the maximum available water falling on

the land in a period of twenty-four hours. On the other hand, in hilly districts larger provision must be made; the drains should perhaps be equal to carrying away the maximum amount of water likely to fall in four hours. It must be remembered in this connection that the proportion of rainfall removed by drainage is very much greater in the winter, when the heaviest rainfall frequently takes place, than in the summer. The following table shows the proportion during the summer six months and the winter six months respectively for the years mentioned [1] :—

TABLE XV.

Filtration and Evaporation from the Soil in Summer and Winter.

Years.	Rain.	Filtration.	Evaporation.	Filtration.	Evaporation.
		APRIL TO SEPTEMBER INCLUSIVE.			
	Inches.	Inches.	Inches.	Per cent.	Per cent.
1836	12·20	2·10	10·10	17·3	82·7
1837	9·80	0·10	9·70	1·0	99·0
1838	10·81	0·12	10·69	1·2	98·8
1839	17·41	2·60	14·81	15·0	85·0
1840	9·68	0·00	9·68	0·0	100·0
1841	15·26	0·00	15·26	0·0	100·0
1842	12·15	1·30	10·85	10·7	89·3
1843	14·04	0·99	13·05	7·1	92·9
Mean	12·67	0·90	11·77	7·1	92·9
		OCTOBER TO MARCH INCLUSIVE.			
1836	18·80	15·55	3·25	82·7	17·3
1837	11·30	6·85	4·45	60·6	39·4
1838	12·32	8·45	3·85	68·8	31·2
1839	13·87	12·31	1·56	88·2	11·8
1840	11·76	8·19	3·57	69·6	30·4
1841	16·84	14·19	2·65	84·2	15·8
1842	14·28	10·46	3·82	73·2	26·8
1843	12·43	7·11	5·32	57·2	42·8
Mean	13·95	10·39	3·56	74·5	25·5

[1] *Journ. R.A.S.E.*, vol. v. p. 151.

A great point to be remembered is that the smallest pipes that are consistent with efficiency should be used, not only because small pipes are less expensive than large ones, but also because they require a smaller amount of excavation of the soil, and consequently the cost of construction is less. Acting upon this principle when pipes were first used in drainage, 1 inch was commonly considered a sufficient diameter, but it has been proved by subsequent experience that pipes having such a small bore are very liable to become choked and useless, consequently the diameter of pipes has gradually increased, until the usual size now employed for minor or lateral drains is 2 inches or 2½ inches in diameter. For sub-mains, delivering only a small quantity of water, 3 and 4-inch pipes are commonly employed, while, for ordinary field drainage, pipes of 6 inches in diameter are usually large enough for the mains. The size used, however, for any drain must obviously depend upon the area of the gathering ground supplying it with water.

Execution of the Work.—The usual time for carrying out drainage is in the autumn or winter, preferably the former. The reason for this is that during the autumn a larger proportion of the land is free from crops than at any other time of the year, while in the case of grass land little growth can be expected until the following spring, so that the turf which is disturbed in making the drains has ample time to become re-established, and its growth takes place freely then. A further reason is supplied by the fact that in the autumn the soil is usually dry, so that it is easily moved, and the labour of cutting the drains is less than if the soil were wet and heavy. There is also less risk of damaging the texture of the soil in carting the tiles on to the land than there would be if the soil were wet. Moreover, the full beneficial effect of the improvement is not felt for some little time after the drainage is carried out, and consequently it is an advantage to get the drainage finished some time before the growing season of the year. The cost of labour, too, is also less during the autumn and winter than it is during the spring and summer, and men can be better spared from ordinary farm work.

When it is decided to drain a piece of land, the first thing to do is to fix upon the outfall—that is, the point at which

the water shall be delivered from the drainage system into an open ditch or stream. Obviously the outfall must be the lowest point in the system of drainage, and if it cannot be determined with certainty by the eye which is the lowest point the level must be used. When the outfall is settled, before any trenches are cut, a general scheme of the system should be decided upon, and carefully marked out upon the land. The line of the main drain must, of course, follow the lowest levels of the land, and if any hollows branch from the mains, sub-mains may perhaps be required to run up each of these. In any case, if there be room for choice, the system should be arranged so as to have as small a quantity of main or sub-main drain as possible, because naturally the expense of these larger drains is very much greater than that of the minor drains. Another point to be guarded against is making the minor drains too long, because if of any considerable length the lower portion of each must be made of larger diameter than the upper portion, as the quantity of water running through will be much greater at the lower end, and so sometimes every minor drain at its lower end would have to be made of the diameter of ordinary sub-mains. In such a case it is better to cut off the minor drains at about half their length by a sub-main running across them, and make a separate system of minor drains lower down, delivering their water into another sub-main. A reference to Fig. 10 will explain this fully.

As far as possible all drains should be kept away from the roots of trees, which may stop up the channel and so destroy its efficiency, and particular care should be taken in the case of mains, because if a main be stopped up it destroys the usefulness of every drain delivering water into it. Another rule to be remembered is that all curves and angles in the drains are to be avoided if possible. It was at one time thought by many that a curved drain was better than a straight one, for it was said to "draw" better; but this is quite a fallacy, for any curve forms an obstruction to the flow of water, especially if the bend be sudden. For example, it has been found that if the resistance to the flow of water caused by a curve having a radius of 20 feet be represented by 100, the resistance caused by a right angle will be 316. This also applies to the way in which lateral

drains should join the mains. Just before making the junction, the minor drains should curve in the direction in which the water in the main flows (see Fig. 11). There is thus less interference with the flow of water in the main,

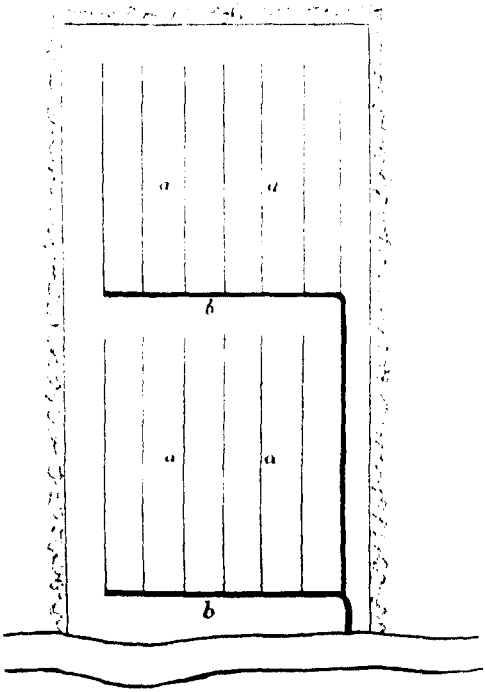

FIG. 10.—a, a, a, a, Minor drains. b, b, Sub-mains.

and it cannot be too strongly emphasised that anything which impedes the flow of water in a drain will cause a deposit of silt at that point, and sometimes a complete stoppage of the channel in consequence. Another point with regard to the junction of minor and main drains is that the minor drains must never join the mains opposite to one another, because if so they are very likely to cause a choking

of the main at that point, with the unavoidable result of causing the pipe to become silted up.

When the future position of the drains has been marked out, the materials for forming the channels, whether tiles or stones, should be carted on to the land and placed in small heaps in convenient positions. This must be done before any trenches are cut, because if the ground be once opened the carts may have to go a long way round to deposit the tiles where required. Cutting the trenches may then begin,

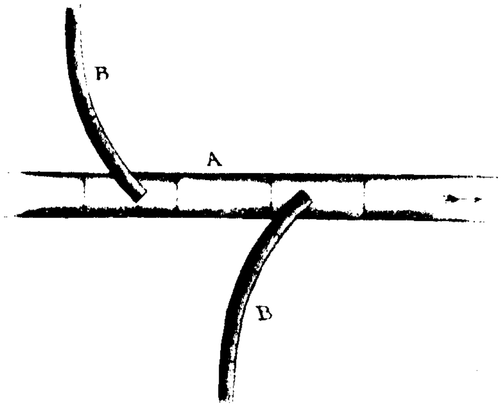

FIG. 11.—Plan of junction of minor drains with main.
A, Main drain. *B*, *B*, Minor drains.

and this is done by taking out a succession of "grips," one below the other, until the required depth is reached. The topmost layer is generally taken out with an ordinary spade, but a saving of labour can be effected by using the draining plough, an implement somewhat like a common plough, but designed to cut on both sides of and beneath the furrow-slice, and to lay it over a short distance away from the edge of the furrow. The draining plough is not, however, an implement which is required often enough by the ordinary farmer to make it worth his while to purchase one, though on estates where draining is constantly being carried out it will amply repay its cost. The common plough is also

sometimes used for turning out the topmost layer, but this does not do the work so well as the draining plough. If the land be under permanent grass, the turf should be carefully cut and laid on one side, keeping it as far as possible in large pieces so that it can easily be replaced when the work is finished. Similarly, in arable land, the surface soil should be kept by itself, being laid on one side of the trench, while the subsoil is laid on the other, so that they can be replaced in their original positions and any risk may be avoided of leaving on the surface material unsuited for the growth of crops.

When the first "spit" has been taken out, the next layer is removed by a special spade having a long narrow blade, which is usually called a "graft." When the graft has been used, a scoop attached to a long handle is employed to finish its work, and this scoop may be one of two kinds, either a draw scoop or a push scoop. These names signify the way in which the implements are used, the draw scoop being drawn towards the man using it, the push scoop being pushed from him. The majority of drainers prefer the draw scoop, and this certainly does neater work in the trench, leaving a smooth, clean bed at the bottom; but on the other hand the push scoop is rather more convenient to empty of the soil it has taken up, especially if it be wet and sticky, so that many men prefer it. Except where the drains are to be laid very shallow, a third layer must be taken out, this being done with a narrower graft than was used before, and then the bottom of the channel is smoothed off carefully with another scoop, which should be of the same size as the pipe to be laid, because a firmer bed is thus obtained for the pipe, as it rests entirely on undisturbed soil. It is in the smoothing of the channel to receive the pipe that the draw scoop particularly excels, because there is less tendency for it to leave small pieces of earth loose in the channel, and consequently the pipes when laid lie more evenly. In the very deepest drains it may be necessary to cut a fourth time again, using a narrow graft, but this is quite the exception. As to the width of a trench which has to be opened, the top should only be wide enough to allow the man digging the trench to work easily, because the wider the drain the greater the amount of earth which has to be excavated, and con-

sequently the greater the cost. Roughly speaking, for a 3-foot drain an opening of 11 or 12 inches at the surface will be sufficient, but the deeper the drain the wider must be the top of the trench.

What has been said above with regard to the width of the trenches does not hold good where the soil is very stony, for then it is necessary to open a wider trench so as to allow of the pipes being laid by hand at the bottom of the trench, and being carefully and evenly bedded. In very stony soils also the scoops do not work well, and it may be necessary to open trenches wide enough to allow of the pick, spade, and shovel being used.

As the cutting goes on it is of the utmost importance that the gradient of the trench—that is, its rate of inclination—should be preserved even and constant throughout. It sometimes happens that changes of gradient are necessary, but usually it is better to avoid them, for the alteration thus caused in the rate of the flow of the water in the channels is likely to cause a stoppage. Usually, however, it is of no use to measure from the surface of the ground in order to preserve the gradient true and accurate, for the slight variations in the surface levels, which are always present, even in the flattest and most even land, are quite enough to impair the permanency of a drain if the depth is regulated in this way. The only satisfactory way of preserving the gradient is by the use of "boning rods," which are instruments like roughly-made T-squares, with, however, the stem of the T arranged so that it can be driven into the ground. Before the work commences one of these boning rods is fixed up at the top of the proposed drain and another at the bottom, in such a way that a straight line drawn between their tops will be exactly parallel to the proposed drain; then, as the cutting goes on, its accuracy can be tested at any moment by the foreman going to one boning rod and looking from its top to the other, while a third is held at any point in the trench by an assistant. If the gradient be correct at every point throughout the length of the drain, the top of the third boning rod will be exactly in a line between the other two.

In land which contains large stones it is often difficult to obtain such an even gradient as one wishes, and some

judgment must be exercised to decide in what way the difficulty may best be overcome. If they be very large it may be better to divert the drain slightly, so as to avoid them, taking care, however, not to make any sudden angles or curves by doing so. If this cannot be done the stone must, of course, be removed in some way; but this gives rise to another difficulty, namely, that when the stone is taken out a large hollow is formed in the bed of the drain, and, generally speaking, no matter how carefully this hollow is filled up it will have a tendency to sink somewhat, and so *to disturb the gradient of the drain.* Where stones must be removed, the ramming of the soil into the hollow left must be done very carefully, and if possible under the master's eye.

Cutting the trenches must be done commencing at the lowest levels, so that as the water finds its way into them it may be able to flow away freely. If the soil be dry, so that no water runs in the trench, it is very common for the trenches to be left open until rain falls, so as to see that the gradients are right, and that there is free passage for the water in the drains. If, however, the gradients have been laid out with proper care there should be no cause for doubt on the point, and consequently there will be no advantage in leaving the trenches open. Indeed, if the trenches be left before the pipes are laid there is a positive disadvantage, for the sides are liable to crumble in slightly either in frost or rain, and in this way the smooth even bed which is so necessary for the pipes may be spoilt. Besides this reason for laying the pipes soon after opening the trenches there is another equally strong, namely, that if water runs in the trenches long before the pipes are laid it will certainly furrow them at the bottom and so again injure the bed of the pipes.

Where pipes are used laying is done by means of a laying tool, consisting of an iron bar a little more than a foot in length fastened at right angles to a long handle. The pipes are first placed conveniently along the side of the trench and are then picked up one by one on the laying tool and laid at the bottom and firmly settled into their places. In doing this the man stands astride of the trench, and can work with great rapidity. This part of the work is,

however, so important that it must only be done by the most trustworthy men, who should, if possible, be paid by the day and not by the piece, for in this way only can hurrying and scamping be avoided. The laying of the pipes, like the cutting of the drains, should be done from the lower end upwards, so that it may keep up with the work of cutting. Where, however, the pipes have to be laid by hand, as in the case already mentioned, where the soil is very stony, it is often convenient to wait until the whole trench is open, and then to lay the pipes from the top downwards, for it is easier for the man to work in this way than up the slope. The man who lays the pipes must also make all the connections between the drains, and should be responsible for the gradient, and in fact for the general construction of the work.

As soon as possible after the pipes are laid the earth should be filled in again, and this must be done with very great care. The soil that was taken out last must be put in first, and *vice versâ*. If the first soil is not put in carefully upon the pipes there is some risk of displacing the latter, and so injuring the drain. In stony soil also there is risk of breaking the pipes if the stones be carelessly allowed to fall upon them. When, however, the pipes are covered to a depth of a few inches no special precautions need be taken, as the pipes are then secured from injury. In any case the soil must be filled up a few inches above the surface of the land, so that in settling it may sink to the right level. This is particularly important in meadow land, where any unevenness in the surface would interfere with haymaking operations.

Another difficulty that must be remembered is the constant tendency of the soil to find its way into the pipes during the progress of the work. To avoid this, whenever no more pipes are to be laid for a time the topmost pipe laid should be stopped with a stone or plug of some sort, so as to prevent the soil being washed into the top of the drain. Similarly, when the drain is finished, its upper end should be plugged or at least surrounded with stones.

All junctions between drains must be made with the greatest possible care, and must be perfectly firm, so as to avoid displacement. It is a good plan, even in small unim-

portant junctions, to place a few stones about them, as this helps to make them firm; but if a junction is important, as, for instance, between mains, it should be carefully surrounded with large stones, which may with advantage be set in lime. Another plan frequently adopted for important junctions is that of causing the several drains to deliver their water into a well, out of which a single main leads. These wells may be made of dry stone or ordinary masonry or brickwork, but where mortar is used in their construction openings through the walls should be left at intervals to act as "weep holes," for otherwise water may accumulate behind them. A point not always attended to in constructing wells of the kind is that the outlet opening must be at a lower level than any of the inlets, otherwise the water will be "backed up" in the latter, which accordingly will become silted up. A great advantage of this system of making important junctions is that, by means of a manhole, they can be inspected, and, if necessary, repaired and cleaned. It is, however, not always convenient to have a manhole on farm lands.

The outfall of a drainage system rarely obtains as much attention as it requires, for unless the outfall be kept free from obstruction the usefulness of the whole system is impaired or destroyed. One frequently sees the outfall of a drain made merely by the last pipe projecting from the side of a stream or ditch; but where this is the case, as time goes on, the water will cause the pipe to become loose and to fall into the stream, and will gradually wear away the soil, so that one pipe after another falls off from the end of the drain. Another disadvantage of this kind of outfall is that the action of frost upon the last pipe causes it to crumble, and so the drain may be stopped up. Accordingly, the last few feet of a drain leading to an outfall should be made of iron piping, and this should be set in brick or stone, the pipe projecting slightly from its surface. The masonry should also extend in the form of an apron in front of the outfall, so that the water running from the pipe may not undermine the structure (see Fig. 12).

Every outfall ought to be laid and covered with a grating, which should be hinged at its upper side, so that it can open outwards under pressure of water from within.

If possible all outfalls should be placed above the flood levels of the streams into which they deliver their water, otherwise, just when the drainage is most required, the whole system will be rendered useless. It is, of course, impossible to avoid this under some circumstances, but it is a point worth consideration.

The cost of drainage varies very considerably, according to the soil and the depth of the drains. Cutting and filling alone will generally cost from 6d. to 10d. per chain for each foot in depth of the drain, but occasionally will exceed even the higher of these prices. This rule, however, is not strictly accurate, for the cost of cutting very deep drains is more in proportion. It should be noted with regard to the cost of cutting, that if the draining plough be used, a saving of about 4d. per chain, or rather less, may be effected. As has been stated above, the laying of the pipes should be done by day work, but, generally speaking, the cost of laying and making junctions, and general supervision, will amount to about 2d. or 3d. per chain. It will, however, depend principally on the number of junctions and their importance.

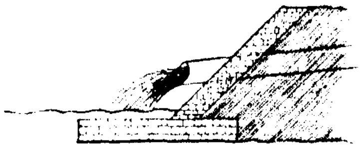

FIG. 12.—Construction of outfall.

Causes impairing the Efficiency of Drains.—There are a number of ordinary causes which tend to impair or destroy a drainage system. The most common of these is the soil gaining access to the interior of the drains. As was shown in dealing with the question of the size of the drains, the smaller the channels the more likely they are to suffer from silting up, and as has also been shown, the slower the rate at which the water flows the greater the tendency there is for the pipe to become stopped. It has also been found that pipes placed too near the surface are more likely to suffer from this cause. Again, in some soils there is greater tendency for silt to find its way into the pipes than in others, and where this is the case, either collared pipes must be used or sheathing pipes, the latter plan being that the drain is placed inside a larger pipe, so that most of the

silt is deposited in the outer pipe while the inner one is comparatively free. This system is, of course, an expensive one, but sometimes is absolutely necessary. Where a drain has become stopped up from this cause the only method of cleaning it is to open it at intervals throughout its length and to pass up a wire or rod from one opening to another, and draw through the pipe a bundle of rags or similar material so as to thoroughly clean out the dirt present. Occasionally the silt will become quite hard and compact in the pipe, and then special rods must be used to break up the deposit, great care being taken not to break or displace the pipes. Where the silting of the pipe depends upon such causes as the stagnation of water in the pipe, owing to uneven gradient, or to inperfect outfall, cleaning the pipe will be of little use, the only remedy being to remove the cause of silting up by reconstructing or improving the drain.

A drain may also very frequently become choked up by obstruction at the outfall, when sufficient pains have not been taken for protecting the latter. Several causes destroying the usefulness of the drain have been mentioned already in dealing with outfalls, such as crumbling of the pipes at the outfall, and, where no grating is fixed at the mouth, by the entrance of rabbits, frogs, etc. Again, cattle sometimes tread in the earth about a badly-made outfall, particularly in dry weather, when they sometimes attempt to drink at the drain. All these causes of disturbance may be avoided by a proper construction of the outfall.

The utility of the system of drainage will also be destroyed by anything causing displacement of the pipes. As already shown, this may take place in some of the soils merely from the weight of the pipes—that is, unless special precautions are taken to prevent it. But, in any soil, the pressure of water may cause displacement if the drain be laid at too steep a gradient. Occasionally rabbits may undermine the drains, particularly in light sandy soils, and so bring about the same result. In any case, the only thing to be done is to take up the drains and relay them, after having, as far as possible, removed the cause of the displacement.

Roots of plants are also a frequent cause of the stoppage

of drains, for sometimes they will extend for a long distance in search of water, and when they get into the pipes they form a closely-matted mass of fibres, in time completely blocking the drain. This, of course, is more likely to happen in drains laid rather shallow, and also in light soils, where plants of all kinds can extend their roots with greater freedom. Trees are usually the worst offenders in this respect; but different kinds vary very much, the most troublesome being the willow, the ash, the poplar, and the elder. The oak and the white-thorn are comparatively inoffensive. But something depends on the age and rate of growth of the individual tree, for it is usually found that young, quickly-growing trees are more likely to block up drains than old, well-matured ones.

When it is found absolutely necessary to lay drains near trees, collared pipes should be used and the joints cemented; but this can only be done for a short distance, for a drain so made acts only as a channel for carrying water, and not as a means of making the soil dry. Another plan, frequently adopted, is to place just below the pipe a layer of gravel. A plentiful supply of water is more often present in the gravel than in the pipe, and consequently any roots extending to the drain will spread all through the layer of gravel without any particular tendency to fill up the pipe, which thus remains free and open for the purpose of draining the soil about it.

The presence of iron in the soil in large quantities is sometimes a source of trouble, as a yellowish-red deposit of oxide of iron is formed in the pipes, quickly blocking them up. Where this takes place to any marked extent there is not much to be done as a remedy, and the best way to avoid the trouble is to lay drains at a very steep gradient in the first instance, so that a rapid flow of water in them may prevent the iron oxide clinging about the side of the pipe. Liming the soil is also sometimes beneficial.

Results of Drainage.—In an undrained soil a large proportion of the rain falling on the surface has to be removed by evaporation, and wherever evaporation takes place a great deal of heat is rendered latent, and therefore such a soil is always a cold one. But when the land is drained a considerable amount of water is drawn off from

below, in this way obviating the necessity of so much evaporation. Besides this, in its passage through the soil the water carries down to the lower parts of it a good deal of warmth, for the rain water is frequently warmer than the soil itself, and any water standing on the surface is likely to become warmed by the exposure to the sun's rays. In either case this comparatively warm water is drawn downwards, and it serves to raise the temperature of the subsoil. In undrained, water logged soil this cannot take place, the warmer water naturally remaining on the surface of the soil, having no tendency to sink and mix with the colder, denser water below it. An experiment carried out by Parkes illustrates this point very well.[1] In a peat bog, before drainage, the temperature of the soil at all depths was, for several years, 46°, except on one occasion, when it fell to 44°. After drainage the following temperatures were observed in the month of June:—

TABLE XVI.

Temperature of the Soil at various Depths.

Date.	Time of Observation.	Temperature at				
		31 Inches.	25 Inches.	19 Inches.	13 Inches.	7 Inches.
June 7	9 A.M.	46	47	48·4	50	52
	2 P.M.	...	...	...	50·5	55
,, 8	9 A.M.	...	...	...	50	51
	2 P.M.		...	...	...	52·5
,, 9	9 A.M.	46·1	47·2	...	49	49
	2 P.M.	...	...	48·5	49·5	52·8
,, 10	9 A.M.	46·2	...	48·6	50	53
	2 P.M.	...	...	...	50·5	54
,, 11	9 A.M.	46·3	47·4	...	51	55
	3 P.M.	...	47·5	48·7	...	59
,, 12	9 A.M.	46·5	47·4	...	51	55
,, 13	2 P.M.	46·8	48	48·8	52	59
,, 14	Noon	47·2	48·4	50·4	53	60·4
,, 15	9 A.M.	47·25	48·6	50·8	53	57·6
,, 16	9 A.M.	47·6	49	51·4	54·2	60
	3 P.M.	...	...	51·8	54	62·5
,, 17	9 A.M.	48	50	52·8	55·6	58
	3 P.M.	48·2	50·1	...	55·8	60·4
,, 18	10 A.M.	48·25	50·2	...	55	56

[1] *Journal R.A.S.E.*, vol. v.

It will be seen from this that the temperature of the soil was raised very much by drainage, even to a considerable depth, while near the surface it varied with that of the air from day to day, and at different times of the day.

The constant passage of water downwards through the soil in the way described has a marked effect in opening its texture, and as it passes downwards the water draws *with it a good deal of air*, so that in time the soil is improved and deepened by the weathering action going on to a lower level than in undrained land. Another benefit is that, particularly in the spring, the air is a good deal warmer than the soil, and consequently in its passage through the soil it tends to raise its temperature. This has a special value from the fact of its being effective chiefly when it is most important that the growth of the plant should be assisted.

As already shown, the rain falling on the surface of the soil contains small quantities of material valuable as plant food, and consequently it is an advantage that the water should be drawn down through the soil so as to give an opportunity for this plant food to be absorbed. A further advantage is that an undue accumulation of soluble salts in the surface soil is prevented, for they are dissolved in the rain water falling on the surface, are drawn down through the soil, and so are eventually removed in the drainage water, unless they have been retained by the absorptive power of the soil. In undrained land, on the contrary, these soluble salts will constantly accumulate close to the surface, for in that case the passage of water is from below upwards, the capillarity of the soil constantly bringing up water to take the place of that which evaporation removes. In this way the amount of soluble salts continually increases in the surface soil, as, of course, they are not removed with the water.

It is found that the presence of oxygen at the roots of plants is essential for their growth, so that it is obviously impossible for any plant to extend its roots below the water-table of the soil in which it grows. By drainage we lower the water-table, and consequently deepen the soil available for the use of crops. The result is that plants growing in a drained soil form a freer and much more extensive root

growth, and, following from this, they are much stronger and healthier. It therefore happens that plants actually suffer less from drought in drained land than in undrained land, because their greater root development gives them a better opportunity of feeding and growing even under unfavourable conditions.

These beneficial results affect the farmer in many ways. The land grows larger crops and they mature more quickly. The quality of his crops is also better, both in the case of arable and of grass land. Where drainage is carried out generally in a district the climate is distinctly improved, becoming warmer, drier, and consequently healthier for man and beast. Sometimes it will enable the farmer not only to keep more stock on his farm, but to have greater freedom in his choice of stock. For example, frequent cases might be quoted where land which formerly always infected sheep kept upon it with the liver-fluke has become quite sound in consequence of drainage. The texture of the soil is also improved in arable land, so that the work of cultivating the soil is reduced, and in consequence of the land drying more quickly after rain the number of days on which work can be done on the land is increased.

Since drainage has become general over the greater part of England there is one result that has become prominent, namely, the effect on the streams and rivers of the country. By drainage, water falling on the surface is carried off the land and into the rivers more rapidly, so that there is found to be a greater tendency for the rivers to overflow their banks than formerly. This makes it more difficult to protect low-lying districts from inundation, and, moreover, affects the use of streams as sources of power. Instead of a comparatively regular flow of water in the stream, it is found that there are alternate times when the stream is so full that much power is wasted, and when it is so empty that there is comparatively little power obtainable. Occasionally it has been found that drainage has affected local water supply, of course from the same cause.

Of the other three kinds of drainage mentioned not much need be said, for they are of much less importance than deep drainage, and their defects and advantages are similar. Surface drainage consists in making a number of channels or

trenches on the surface of the ground, which are left open so as to carry away the surface water. They cannot usually be made deeper than 18 inches to 2 feet, and therefore do not lower the water-table in the soil very materially. The system is, however, very useful where the land is not of much value, so that the occupation of the surface by the channels does not matter, and as a first means of draining very wet land, particularly peat bogs, it is necessary in order to allow the soil to consolidate sufficiently for subsequent deep drainage. In plantations also open channels are in many respects preferable to covered drains, as they are not liable to be stopped by the roots of trees and other plants, and though they are, of course, likely to become filled up with leaf refuse, they can easily be cleaned out at small cost. The system of surface drainage is not generally applicable to arable land, except in a modified form, as permanent channels running across the surface of the land would interfere very seriously with the work of cultivation. On heavy land, however, a form of surface drainage is adopted, in which open furrows are made, running down the slopes, which are in reality the channels of a more or less temporary system of surface drainage. In grass land another modification is sometimes seen in the high-backed ridges constantly found in strong land districts. These have been gradually formed by making small surface grips in the furrows and throwing the soil taken out on to the ridges. This process, continued year after year, gradually increases the ridges to a considerable height above the furrow, and renders a great part of the surface dry.

In making the channels it is necessary for the sides to slope considerably, the actual slant being regulated by the character of the soil. This is necessary to prevent the channel being filled up by the crumbling in of the sides, which is specially likely to occur where stock, and particularly cattle, are kept on the land. It may be noted in passing that surface drainage is better suited for sheep pastures than for those where cattle feed.

Sink-hole drainage, or Elkington's system, is only locally applicable, and may be described as a system of tapping springs in the soil and thereby relieving pressure of water. Frequently, by drawing off the water stored at a higher

level, springs may be altogether dried up, or the pressure so far relieved that they are unable to force their way through the soil of lower-lying ground. The borings for drawing off water may sometimes be made to a considerable depth, and it is reported that Elkington sometimes made borings to a depth of 15 feet, and for convenience of working sank shafts of a diameter of 8 or 9 feet, so as to allow two men to work freely at the bottom. When the work was completed these shafts were filled with large stones, so as to prevent the soil falling in and blocking up the opening, and some means were taken of carrying off the water which rose through the stones, either by a surface or a covered drain.

Arterial drainage consists of a provision of main water-courses to carry away the water from minor drainage systems, or the improvement of existing water-courses. In the provision of main water-courses it is necessary to maintain a certain rate of flow in the channel, to prevent the deposit of silt, and so to save expense in dredging or otherwise cleaning out the channel. It is stated that in the case of large rivers a fall of 1 foot per mile is sufficient to keep its bed clear: for streams of moderate size, 2 feet per mile is required, while in large ditches 8 feet per mile is necessary. Also, to keep up the rate of flow, whether a channel be full or empty, it is necessary to make the sides slope very much, so that the channel shall be very narrow at the bottom. It also has the advantage of preventing the sides crumbling away.

While a certain minimum fall is required to keep the channel free from obstruction, there is a certain maximum which should not be exceeded. This maximum will depend upon the material of which the channel is made, for if it has great power of resisting the wear of water flowing over it, a greater fall may be given than if it was a soft, easily crumbling material which will wear away rapidly. The following is given as the quickest allowable rate of flow of the current close to the bed of channels made of the materials mentioned.[1]

[1] Rankine's *Civil Engineering*.

Table XVII.

Maximum Velocities of Current in Channels of various Materials.

Soft clay	0·25	foot per second
Fine sand	0·50	,, ,, ,,
Coarse sand and gravel as large as peas .	0·70	,, ,, ,,
Gravel as large as French beans . .	1·00	,, ,, ,,
Gravel, 1 inch in diameter . . .	2·25	feet per second
Pebbles, 1½ inches in diameter . . .	3·33	,, ,, ,,
Heavy shingle	4·00	,, ,, ,,
Soft rock, brick, earthenware . . .	4·50	,, ,, ,,
Rock, various kinds	6·00	,, ,, ,, and upwards

The water-courses should be made with as few curves or angles as possible, for every change in direction in the channel causes a partial obstruction to the flow of water, and increases the friction. Similarly, where an existing stream follows a serpentine course, as is frequently seen, much advantage may be gained by making a straight cut for the water to flow in, in place of the old channel. There is thus less resistance to the flow of water, and consequently less chance of flood, while, owing to the shorter length of the new channel, a better fall is obtained.

CHAPTER IX

IRRIGATION

IRRIGATION consists of the occasional flooding of the land with running water. At first sight this appears to be the opposite of drainage, but it must be noticed that the water used must be running, for if any stagnation takes place the crops growing will be injured instead of benefited. Irrigation is not of so much importance in England as in warmer countries, and with us is principally employed on grass land. In India, on the other hand, there is a large district which would be absolutely unproductive except for irrigation, by means of which all kinds of crops are raised.

Whatever system be adopted for irrigating the land, it must be remembered that drainage must first of all be attended to, for otherwise the soil will be saturated with water, which will be unable to flow away quickly enough.

There are two systems of irrigation which are most frequently employed :—

1. The Ridge-and-furrow System.
2. The Catchwork System.

The ridge-and-furrow or "bed-work" system is the plan adopted for moderately level land. The surface is laid out in ridges or *banks* about two rods in width, along the top of which run channels for delivering the water on to the land, while along the furrows between are a second series of channels for collecting the water and carrying it away from the land (see Fig. 13).

The width and depth of the channels is so regulated that they are always full of water, and so that the water trickles

evenly down each side of the ridge, covering the whole surface. The expense of laying out the land in the first instance is considerable, averaging from £30 to £40 per acre; but the cost varies according to the convenience of water supply and the modifications which have to be adopted to suit the levels of the land.

The catchwork or catchwater system is that commonly employed for sloping land. Channels are made at intervals, running across the slope, with only sufficient fall to keep up a steady flow of water. The water is introduced into the top channel, and its quantity is so regulated that it overflows down the slope. It is next collected by the second channel,

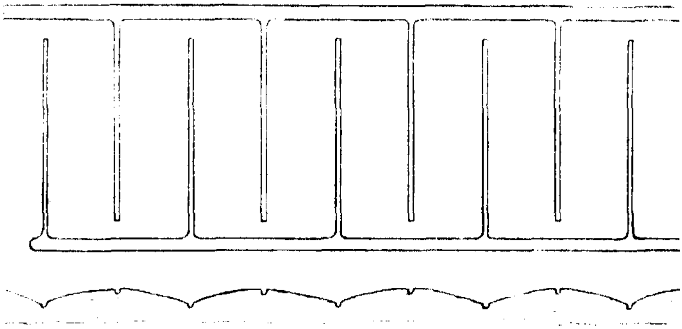

FIG. 13.—Ridge-and-furrow irrigation. *A*, Plan. *B*, Section.

out of which it once more flows down the hillside, to be again gathered up by the lower channel, the number of channels depending upon the length of the slope. It is necessary to have a succession of channels in this way, for otherwise the water would form runnels down the slope, and would not cover the whole surface evenly. This system is generally a very cheap one to lay out, the chief expense being in bringing the water to the top of the slope.

Besides the above systems of irrigation proper, there are others which are sometimes adopted, in which the periods of flood of streams are taken advantage of, and the water turned over the surface of the adjacent land by means of some kind of floodgate or sluice. Another modification largely adopted

in some districts consists in flooding the land and causing the water to stand for a short time until any sediment it may contain has been deposited on the surface of the land. In this case, however, the advantage gained is more from the addition of silt and mud to the soil than from the ordinary effects of irrigation. *This is sometimes called "warping" or "wet warping."*

Speaking of irrigation proper, one of the first things to be considered is the quality of the water that has to be employed. As a rule the best water for the purpose contains carbonate of lime, such, for instance, as that supplied by streams in chalk or limestone districts; but occasionally cases are met with in which too much lime occurs. The presence of iron in the water in any considerable quantity is unfavourable for the purpose, and water flowing from peaty land is also unsuitable. Two good indications that the water is suitable for the purpose may be mentioned, viz. the presence of trout in the stream, or of water-cress in large quantities.

The management of irrigated land in this country varies to some extent in different districts. In the case of grass land the water is usually turned over the land at intervals throughout the winter, so as to force on the growth of the grass and produce an early crop. Care must be observed that the water is neither turned on nor turned off during the continuance of frost. Preferably, the land should be as dry as possible during the frosty weather; but if a frost comes on while the water is running over the land, it should, if possible, be allowed to continue running till the frost ceases, for the running water will partially protect the plant from the cold. In any case care must be taken not to allow the water to run too long at one time, for otherwise a film of slimy material will form on the surface, and this is a sure sign that the plant is being injured. The better the water is for the purpose of irrigation the longer it may continue to run at one time; and the colder the weather the more slowly the film will be formed. When the crop of grass has made sufficient growth, it is usually fed off, and the land again flooded as soon as possible. In the south and south-west of the country, two, or sometimes three crops may be obtained in this way before it is necessary to lay up the land for hay; but, more commonly,

when the grass has once been fed down it is on the safe side not to attempt to feed it off again. Whichever plan may be adopted, as soon as the stock are finally removed, the land is flooded, and then left till the crop is ready for cutting to hay. After the hay is cleared, the water is once more turned on, usually for a rather short time, owing to the hot weather, so as to force on a further crop. In this way, by judicious management, the maximum number of crops may be obtained in the season. In the case of arable land, the management must be somewhat modified, for not only have the requirements of the crops to be considered, but also the exigencies of cultivation. Usually, the water is not left running so long at one time on arable as on grass land. In this country, where the system is followed at all, the irrigation of arable land is usually carried out with sewage.

Effects of Irrigation.—In dry seasons a very important advantage gained is that both plant and soil are kept moist, and *consequently the former is able to grow freely in spite* of drought. In winter, running water is generally warmer than the soil, and consequently the flooding raises the temperature of the latter, and hastens the plant growth. Water also acts as a carrier of plant food to the roots of the crop, and it must be remembered that in nature water is never absolutely pure, and almost all water used for irrigation contains matter, both in solution and suspension, much of which is valuable as plant food. In this way the soil is eventually enriched, and to this extent irrigation acts as manuring to the plant. Various changes are also brought about in the soil by the action of water, the substances the water contains, and the air it carries into the soil, by which the dormant useless plant food is changed into available matter. As far as the plant is concerned the chief effect produced is an increase in its luxuriance, far larger crops being produced, though they are more watery in their composition.

CHAPTER X

MIXING SOILS, MARLING, PARING AND BURNING, CLAY BURNING, PLANTING, LAYING DOWN TO GRASS

Mixing Soils.—This operation, as its name implies, consists of adding one kind of soil to another. It is also known in some districts as "warping," or "dry-warping," to distinguish it from the "wet warping" already described. It is also variously named "claying," "marling," etc., according to the kind of material added to the land. Speaking generally of the operation of mixing soils, it may be said that benefit more often results from the addition of clay and materials of that kind to light land than from the addition of sand to heavy land. The reason of this is obvious, for in the former case not only is the mechanical condition of the soil improved, but also its chemical composition, for clay almost always contains a certain amount of plant food, in which sandy land may be deficient. It will also be observed that the addition of clay to sandy land is of value in improving the soil in its relations to moisture — that is, in just those particulars in which sandy land is usually most deficient. Besides this, the action of the clay is important in increasing the absorptive power of the soil—that is, its power of absorbing and retaining the constituents of plant food. On the other hand, if sand be added to a clay soil it certainly improves its texture, making it more porous and easy to work, but it adds little or nothing which is of direct use to the plant, or which improves the power of the soil to hold and retain manure. In the comparatively rare instances in which any considerable quantity of organic matter is added to the soil in this way the case is

of course different, as the action of the organic matter is not only to improve the texture of both heavy and light land, but it also adds plant food and increases the absorptive power of soils, particularly if they be sandy.

The method in which this improvement is carried out varies under different circumstances. In some cases the material to be added to the soil is found lying immediately beneath it, and when this happens the improvement can be carried out with the least possible expenditure. The usual plan is to get at the underlying material by quarrying in any convenient part of the field, or, in some cases, by sinking a shaft and making what is known as a bottle-mine. In other cases trenches are opened at intervals all over the land, and the underlying material is taken out of them and spread at once on the surface. All these plans have their drawbacks. In the case of ordinary quarrying a certain amount of surface is injured and rendered useless; or if shafts be sunk some care and expense must be incurred in propping the workings when they are no longer of use, in order to support the surface; while if trenches be opened a large proportion of the top soil is disturbed. It will often happen, however, that the material has to be brought from some distance, in which case the advisability of carrying out the improvement must depend on the expense of carting the material. If the distance is considerable carts must be employed, but for short distances wheelbarrows are more economical. The amount of clay added to the soil will usually range from 50 up to 100 cubic yards per acre, while in special cases even heavier dressings than these are used. The expense of moving such large quantities of earth, however, will frequently render very large dressings extravagant.

Marling.—Where marl is applied to the soil the process followed is the same as for mixing other descriptions of soils, and to some extent the results are the same. The benefit of marling will, however, depend upon the kind of marl employed. One of the most important marls used in this country is the chalk marl, which contains very large quantities of carbonate of lime, but is also valuable on account of the phosphoric acid, potash, and soluble silica which it contains. It improves the soil both by changing

its physical properties and increasing its stores of plant food. Clay marls are also frequently employed, and they are particularly valuable on light sandy land. They contain, as their name implies, large quantities of clay, mixed, of course, with a certain amount of carbonate of lime. Other kinds of marls are sometimes employed, such as shell marl, etc., but not so frequently as the two mentioned above. It must be remembered that the carbonate of lime contained in all marls has an important action upon the soil, of the same kind as when that material is added in any other form. This point will be dealt with in greater detail in the consideration of liming.

Paring and Burning.—This method of improving soils is not, properly speaking, absolutely permanent, but stands to some extent in a position intermediate between permanent and temporary improvements. As the term implies, it consists of paring the surface to a slight depth and burning the part of the soil so pared, afterwards spreading the ashes on the land. Till recently this was a very common way of breaking up grass land, either permanent or temporary, but of late years the practice has very largely fallen into disuse, so that now it is, comparatively speaking, exceptional.

The method of effecting the improvement is, first, by paring the surface with a paring plough, working at a depth of about 1½ inches or a little more. The turf so pared is allowed to dry, and is broken up by means of drag-harrows, or occasionally by ploughing across the lines of the previous furrows. When as dry as possible, the burning commences, a number of fires being kindled at convenient intervals over the land, some straw and faggot wood being employed for lighting them, and then dry turf is added to the fires so made, and more and more turf added as the fire gains strength. It is important, however, that the burning should take place slowly, and to effect this the fire must be smothered in continually, never being allowed to burn up strongly. For this reason the work must be continually watched, and as fast as the fire burns through more turf must be added to the heap, until the whole of the turf has been placed on the fires. The fires are then allowed to burn out, and the ashes, when cool, are spread on the land. Some difficulty is often experienced in windy

weather or exposed situations in getting the heaps to burn evenly, for the fire has a great tendency to burn through at one side of the heap while the other side is scarcely burnt at all. The only way to avoid this is for the fires to be even more closely watched than is necessary under favourable conditions. Formerly the paring of the surface was effected by means of the "breast plough," a hand implement, but this method was very slow compared with the paring plough, and the work done was more expensive.

The benefits which result from paring and burning are, first, that the texture of the soil is improved. This, of course, is particularly the case in heavy land, where the effect of burning the clay is to render it lighter to work and more porous and absorbent of manurial matter. The action of heat also apparently renders some of the dormant plant food of the soil available. If any carbonate of lime is present in the soil, the process of burning will convert it into the state of quicklime, and in that condition it has a much more powerful effect upon the other constituents of the soil, and so increases the amount of available plant food present. Besides this, paring and burning forms the quickest and easiest way of obtaining a fine tilth on an old sward, so that time may be saved in obtaining a suitable seed-bed for the next crop. It is also useful in destroying any weeds or insects that may be present in the soil, and in this respect particularly it is of value in breaking up leys of several years' standing.

It must be remembered, however, that the process of burning the surface soil destroys all the accumulation of organic matter which results from the growth of grasses or other plants for any considerable time, and it practically drives off the whole of the nitrogen contained in the soil, so that one great advantage of leaving land under grass for a time is lost, namely, the enrichment of the soil in organic matter and nitrogen. Under certain circumstances the loss may be disregarded, as, for instance, where a peat soil is to be dealt with, for there the amount of organic matter is so very large that its loss in the first inch or so of the soil is a matter of no consequence.

The organic matter may be partially restored to the soil by the addition of bulky organic manures, or by what is

known as "green manuring," that is, the system of growing a green crop to be afterwards ploughed into the soil. By this means the crop is used to collect carbon from the air and build up organic compounds, which are afterwards returned to the soil when the plant is ploughed in.

Clay-burning.—Clay-burning is comparatively seldom carried out, though it was formerly more common than at present. It consists essentially of burning or roasting clay at a dull red heat and afterwards adding it to the surface soil. It is an improvement particularly adapted to very heavy land, on which only it produces its full effect. The method of burning usually adopted is first to remove the surface soil and then to dig out the clay required from beneath. The surface soil must be kept separate, so that it may afterwards be returned to its place without undergoing the process of burning. By this means loss of the organic matter and nitrogen in the soil is avoided. The burning of the clay is carried out in small heaps, these allowing of a better regulation of the temperature than larger ones. The fires are started in the same way as in the case of paring and burning, but a little coal must be used, thin layers of which are made to alternate with thicker layers of clay. Just as in paring and burning, so in this case, the fires have to be constantly watched in order to prevent their burning through, it being of very great importance that the fires shall burn as slowly as possible, so as to avoid over-burning the clay and converting it into a material like brick. The following figures are given by Dr. Voelcker[1] to illustrate the importance of not over-burning the clay:—

[1] *Journal R.A.S.E.*, vol. xii. p. 502.

Table XVIII.

Percentage Composition of Clay in its Natural State and after Burning.

	Natural State.	Slightly burnt.	More strongly burnt.	Over-burnt.
Insoluble inorganic matter (in dilute hydrochloric acid)	84·100	80·260	81·845	85·309
Soluble inorganic matter .	6·740	10·580	8·955	5·391
Containing—				
Silica . . .	1·450	1·380	1·580	1·150
Carbonate of lime .	0·740	0·420	0·550	0·188
Potash . . .	0·269	0·941	0·512	0·544
Soda . . .	0·220	0·336	0·314	0·104
Phosphoric acid .	0·380	0·165	0·128	...

As fast as the fire burns through the heaps more clay is added, so as to stifle it down, until the heaps are about 3 or 4 feet high, when they are allowed to burn out. If larger heaps are employed the clay is liable to be over-burnt, owing to the intense heat, and consequently the result will not be so good.

As will be seen from the figures already quoted as to the composition of burnt clay, the chief effect is an increase of the amount of soluble matter in the clay. In this way dormant plant food is rendered available, and to some extent the burning will take the place of manuring—that is, it increases the amount of plant food ready for the plant's use. Besides this, a further advantage is gained in the physical texture of the soil, for burning renders the clay more porous, and also increases its absorptive power.

It may be noticed in this connection that, owing to this last property, burnt clay is often used for placing at the bottom of manure heaps, and sometimes at the bottom of sheep-sheds and similar places, for the purpose of absorbing the liquid manure and preventing a waste of its valuable constituents. Over-burnt clay is also of some use in estate work for making concrete, where other material is not available, and also occasionally in making paths and roads.

Planting.—Planting the land with trees is a method of improvement sometimes adopted, and is particularly useful in the case of soils which are either too heavy, too sandy, or too shallow for profitable cultivation. The object in planting is to obtain some return from the land and at the same time to improve it, and this can only take place if the trees planted are carefully chosen to suit the soil in which they are placed. Some trees, however, seem incapable of improving the soil in any appreciable degree, and should be avoided if possible. The extent of the improvement caused by the growth of trees seems to depend upon the amount of leaves produced each year, and on their composition, it having been stated that the greater the proportion of mineral matter contained in the leaves the greater the improvement to the soil. The rate at which the leaves decay seems also to have an effect, for where they decay very slowly the improvement seems almost nil.

At first sight it may appear that the addition of the mineral matter to the soil in the form of leaves cannot do much towards improving the land, but it must be remembered that the mineral matter is drawn from the lower layers of the soil by the roots of the trees and is then added to the surface soil, which is thereby enriched at the expense of the subsoil. A further improvement sometimes results from the organic matter in the leaves, this being formed by the plant from food received from the air. In the case of sandy or gravel soils particularly, the addition of organic matter in this way is very important, both from chemical and physical considerations.

Laying down to Grass.—Considered solely as an improvement, the result of laying land down to grass is very similar to that of planting it—that is, the grasses growing in the soil continually receive food from the air and subsoil, and a great part of this food is returned to the surface soil as organic matter and mineral matter respectively. Accordingly, in the case of old grass land we find that the soil is particularly rich both in the organic matter and in those mineral substances essential to plant growth, and the dark colour which such soils always exhibit is due to the accumulation of organic matter. The extent to which any soil is capable of improvement depends very largely on its texture.

In heavy land the air has very little access to the soil, and consequently the oxidation and decay of organic matter is slow, and a very large accumulation may thus take place. In light land, however, the reverse is the case; oxidation is very rapid, and the accumulation of organic matter is proportionately slow. It is, perhaps, largely due to this that we generally find the best old pastures on rather heavy soils.

CHAPTER XI

LIMING

LIMING is not a permanent improvement in the strictest sense of the word, for its results are seen only for a comparatively short series of years. It must therefore be considered as more or less intermediate between permanent and temporary improvements. Lime may be applied to the land in several forms, the chief of which are caustic lime or quicklime, slaked lime, and mild lime, such as chalk, limestone, etc. In either case the benefit obtained will partly depend on the impurities that the lime contains, as well as upon the form in which the lime is used. The chief of these impurities are—

1. Earthy material.
2. Carbonate of magnesia.
3. Phosphate of lime.
4. Sulphate of lime.

The earthy material is of no value from an agricultural point of view, but merely serves to dilute the pure lime, consequently the larger the proportion of earthy matter present the less the value of the lime. It must be understood, however, that lime containing such impurity is not necessarily of low market value for other purposes, for pure lime is not suitable for many kinds of building work. In quantity the earthy material will vary from less than 0·5 per cent to 30 or 40 per cent.

Carbonate of magnesia is present in most limestones, and if in small quantities does not affect the use of the lime appreciably, but if present in large quantities, such as we

find in the so-called magnesian limestones, where occasionally as much as 50 per cent of the limestone consists of carbonate of magnesia, the properties of the lime are affected, and when it is burnt it is known as "scorching" lime, which must be used on the land with very great caution, or more harm than good will result.

Phosphate of lime is usually found in limestones, and is of value as a source of phosphoric acid to the plant. The amount, however, is usually rather small, ranging from a mere trace up to 1·25 per cent or sometimes more.

Sulphate of lime is also frequently present, though not usually in large quantities; but its value is comparatively slight.

From the presence of varying quantities of these impurities it will be readily understood that the value of the limestone for agricultural purposes will vary considerably. The following table shows the composition of several different limestones, and illustrates the variation in the amount present of the different constituents[1]:—

TABLE XIX.

Percentage Composition of Limestone.

	Portland Limestone.	Kimeridge Limestone.	Great Oolite.	Magnesian Limestone.	Upper Chalk.	Silurian Limestone.
Carbonate of lime .	79·0	75·7	94·59	51·1	98·40	44·6
Carbonate of magnesia . .	3·7	...	2·50	40·2	0·08	3·6
Silica . . .	10·4	15·0	...	3·6	1·10	51·4
Iron and alumina .	2·0	8·2	1·20	1·8	0·42	...
Water, etc., and loss	4·2	1·1	1·71	3·3	...	0·4
	99·3	100·0	100·0	100·0	100·0	100·0

When lime is required for use in the caustic state the limestone must be burnt in order to change the carbonate

[1] Prestwich, *Geology*, vol. i.

of lime it contains into a state of quicklime. The change resulting from the burning of lime is represented by the following chemical equation:—

$$CaCO_3 = CaO + CO_2$$

carbonate of lime produces quicklime and carbon dioxide.

The burning may be carried out in two ways, either in the clamp or heap, or in the kiln.

The former of these two methods is comparatively seldom adopted, owing to the rather unsatisfactory results obtained, and because the cost of burning the lime is rather greater. It is, however, sometimes convenient when a small quantity of lime is required at any place at a distance from ordinary supplies. The method consists of burning the limestone in the same sort of way as in the case of clay-burning, with the exception that the heap is made much larger, and that the layers of fuel and limestone are considerably thicker. Burning in this way takes a considerable time, and there is great risk of the result being spoilt by stormy weather, and consequently it is not a plan that can be recommended under ordinary circumstances.

Kilns for burning limestone are funnel-shaped structures, the wider opening being at the top and a small horizontal opening at the bottom. This is built of masonry and lined with firebrick or stone, which is able to resist the effect of heat. In this kiln a fire is kindled, and alternate layers of coke, or sometimes coal, and limestone are put in from the top. If coal is used special care must be taken that it shall not be placed immediately touching the sides of the kiln, for otherwise it has a tendency to run together and cling to the sides, and so hinder the gradual settling down of the material in the process of burning. As the burning goes on the lowest part of the limestone is gradually converted into quicklime, which is removed, when the process is complete, through the opening at the bottom of the kiln, in this way allowing the material above to sink down lower in the kiln. More layers of fuel and limestone are added above, and so the process goes on, limestone and fuel being continually added at the top and quicklime being taken out below. In this way a kiln may be kept at work until repairs are necessary, the actual time varying according to

the construction of the kiln and the materials used. Fig. 14 shows the section of an ordinary limekiln for producing lime in comparatively small quantities.

Quicklime is usually applied immediately to the soil, and should preferably be put in heaps on the land and slaked as soon as possible by the addition of water. This slaking must be done gradually, the water being added slowly and stirred with the lime, otherwise the latter has a tendency to set into hard lumps instead of falling to a fine powder. This result of the slaking, namely, causing the lime to become

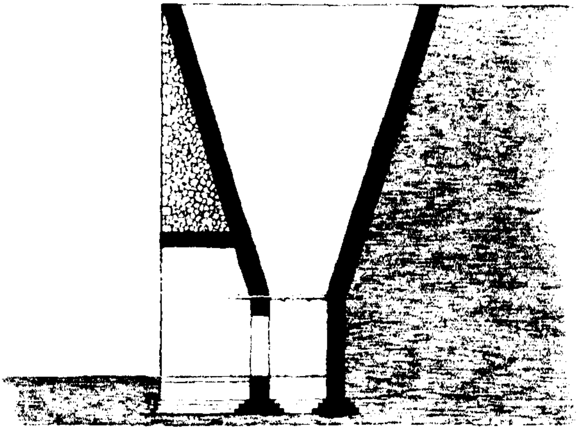

FIG. 14.—Section of Limekiln.

very finely divided, is one of the great advantages of using quicklime for application to the soil. A more common plan of slaking the lime, though an inferior one, is to allow it to become air-slaked, that is, to slake itself by means of the rain and the water it is able to take up from the air. This action is necessarily slow, and a long time must elapse before the whole heap becomes air-slaked. During this time the slaked lime most exposed to the air will also take carbon dioxide from the air, and again become carbonate of lime, thus losing the caustic properties of quicklime. It must be

noted that slaking does not diminish the caustic properties of lime in any degree.

The amount of quicklime applied to the land varies a great deal according to circumstances. For instance, the deeper the soil the larger is the quantity of lime that may be applied; so also in badly-drained land more lime may be applied than on well drained land, because more is required to combine with the acids in the soil. Again, more lime may with safety be applied on arable land than on pasture land, other things being equal, for in the former case the lime is mixed with the whole of the surface soil to a considerable depth, but in pasture land it is merely spread on the surface, and for some time at least is only mixed with the first few inches. The actual quantity applied at any one time must also depend on the extent to which lime has previously been used on the land, and the longer the interval which has elapsed since the last dressing of lime, the larger the quantity that must be applied. On the average, the quantity applied to arable land in districts where liming is customary is about two tons every five years or the equivalent; that is to say, if ten years are allowed to elapse between the dressings about four tons will be applied, if fifteen years, six tons, and so on.

Generally speaking, on grass land it is better to apply lime in small dressings at short intervals rather than in very heavy dressings at any one time, because lime has a great tendency to work downwards in the soil, and consequently in grass land, where it is never disturbed, it very soon gets too low to be of much use to the plants. In arable land, on the other hand, the ploughing of the land tends to counteract this sinking of the lime in the soil, and so it is kept for a long time mixed with the surface soil.

The first effect that caustic lime has when it is added to the soil is that it combines with any acids that may be present in the land and neutralises them, that is, forms compounds which are harmless to the plant. This is a matter of considerable importance, as in many soils, particularly if containing large quantities of organic matter, there is a constant formation of acid, which renders them unfit for the growth of plants, unless these acids be removed by liming, drainage, or other means. Liming is also of particular

importance in manufacturing districts, where there is a large consumption of coal, the smoke of which contains various acid compounds of sulphur, which sooner or later are brought down into the soil and tend to make it sour. In the case of arable land, where the soil is continually being stirred and cultivated, these acids are comparatively easily washed down through the soil, and are removed in the drainage water; but in grass lands the soil is quite undisturbed, and in many cases these acids accumulate to a serious extent in the first few inches of the soil. If this happens the quality of the grass is very much injured, and sometimes the amount of produce is reduced very materially. The evil effects of smoke on the land can be counteracted by frequent small dressings of lime, which serve to neutralise the acid and so keep the soil in a sweet condition. It must be understood that the action of the acids in smoke is only one of the injuries inflicted by it upon farm crops, and that liming has no effect in counteracting the others.

Quicklime added to the soil is also useful by acting upon both the organic and the mineral constituents, and breaking them up to some extent so as to make dormant plant food available for the use of plants. With regard to the organic matter, lime acts chiefly by hastening its decomposition, and so changing the organic nitrogen into the form of ammonia, which readily becomes available for the plant. This, however, is done by the actual destruction of the organic matter in the soil, so that it must be remembered that liming can be done too frequently, for if the organic matter in the soil be reduced below a certain quantity, the physical properties of the soil will be injuriously affected, and further dressings of lime will give little or no result, because there is no organic matter for them to act upon. Accordingly, it is found that the amount of lime used, and the frequency with which it may be applied must depend in great measure on the amount of organic matter in the soil. The same thing holds good with regard to mineral matter, but in a less degree, owing to the comparatively large amount of mineral plant food generally present.

Another way in which lime acts when added to the soil is as plant food. This, however, is comparatively unimportant, for most fertile soils contain sufficient lime for the plant's

requirements, so that the benefit obtained from the use of lime is *usually rather because it renders available material which* is already present in the soil than because it adds plant food to it. If the soil be deficient in lime, however, the addition of it to the soil in some form is essential.

The mechanical action of lime is also worth noticing, particularly in opening the texture of heavy land. Indeed, if liming be frequently resorted to, or if too large a quantity be added at one time, the soil will sometimes become too open in texture, and crops growing during the winter will be liable to be thrown out of land in time of frost. This action of frost is far more noticeable in all soils containing lime than in those where it is deficient.

When lime is used in its mild form, unburnt, it is somewhat similar in its action to quicklime, but in a less active manner. It breaks up both the organic and mineral constituents of the soil to some extent; but perhaps it acts most markedly in neutralising acids in the soil, and in improving its physical properties. In the case of light land particularly the power of the soil to retain moisture is very much increased, while in soils already deficient in organic matter the use of mild lime is preferable to that of caustic lime, as the organic matter is not destroyed to the same extent. The most common form in which mild lime is applied is as chalk. This should be quarried and applied to the land during the autumn or winter, so that it may be exposed to and broken up by the frost, after which it can be spread evenly on the soil. If it is not exposed to the frost, it frequently becomes very hard and gives a great deal of trouble in breaking up and spreading. Various other forms of carbonate of lime are sometimes used. In some districts shell sand is obtained in large quantities, and is applied to the land either direct or after burning. The scrapings of limestone roads are also used for application to the land, and act as a dressing of mild lime.

Another form in which lime is often used is as gas-lime, that is lime after it has been used for the purification of coal-gas. Gas-lime consists partly of caustic and slaked lime. It also contains carbonate of lime, sulphate of lime, and a number of other compounds of lime containing sulphur. Most of these last-named sulphur compounds are poisonous both to

plants and animals, and consequently gas-lime, as it is obtained at the gas-works, is not suited for immediate application to the soil. By exposure to the air, however, for a considerable time, oxidation takes place, and these various substances, such as sulphite of lime, sulphide, etc., are converted to sulphate of lime, in which form they are harmless. It must be remembered, however, that sulphate of lime is not often of much value for application to the soil, and consequently its presence in any considerable quantity may be a drawback to the use of gas-lime. The question whether it is more economical to use gas-lime or quicklime must be determined with reference to their relative price and the distance from which the two materials have to be carted. Weight for weight, gas-lime is not nearly so valuable to the farmer as quicklime, for it contains large quantities of substances he does not require.

The poisonous properties of fresh gas-lime sometimes give it a special use for destroying insect pests or weeds. Where used for either of these purposes, a heavy dressing is applied to the land direct from the gas works, and thus frequently insects or weeds can be got rid of when other means would be useless. It will be understood, of course, that such a dressing can only be applied to the land when free from crops. Some interval also must be allowed to elapse before any crop is sown, in order to allow of the oxidation of the poisonous materials so as to render them harmless.

CHAPTER XII

MANURING—CLASSIFICATION OF MANURES

MANURING is, *strictly speaking, a temporary improvement*, but includes all gradations, from that benefiting a single crop only to one which lasts for many years. This difference depends upon the quickness of the action of the manure and on the power of the soil to absorb it. The immediate effect of a manure depends—

1. On its solubility, and
2. *On the suitability of the plant food which it contains for the use of the plant.*

In deciding the question as to what kind of manuring shall be employed under any given circumstances, the condition of the soil must first be considered, that is, the amount and kind of plant food present. The condition depends principally upon the previous cropping and management of the land, and also to a great extent upon the rate at which dormant plant food becomes available by means of natural agencies, and upon the absorptive power of the soil. With regard to nitrogen, its influence on the productiveness of the soil depends also on its state of combination and the rate at which nitrification can go on. The preceding season will influence the amount of available nitrogen in the soil, for nitrification proceeds more rapidly in a hot season, while a wet one will wash away a great part of the nitrates formed. For example, after a wet winter the wheat crop is often unhealthy in colour and is very much benefited by a dressing of nitrogenous manure. This is owing to the rain having washed away from the soil the nitrates formed during the preceding summer by the nitrifying organisms. A dry

winter, on the other hand, even if cold, will generally be more suitable for the wheat crop, which will have a stronger, healthier appearance in the spring.

Next to the condition of the soil, the requirements of the particular crop to be grown must be considered, and this can only be decided upon with certainty by reference to experience. The chemical composition of a crop is little or no guide to the plant food it requires in manure. For example, the leguminous crops are generally extremely rich in nitrogen, but owing to their exceptional power of obtaining nitrogen through the medium of the organisms found in their root tubercles they do not generally depend upon manuring for supplies of this element. It has been found by experiments often repeated that ordinary farm crops on soils of average composition require generally only three constituents of plant food to be added, namely, nitrogen, potash, and phosphoric acid. Occasionally lime and magnesia are also required, but usually these and all the other essential constituents of plant food are present in sufficient quantity in the soil. Of the three chief constituents of manures, as a rule, it is not necessary to apply all to every crop grown, and they need hardly ever be applied in quantities sufficient to supply the plant with the whole of the nitrogen, phosphoric acid, and potash that it requires, for there is always a considerable amount of available plant food derived from natural sources present in a fertile soil.

The crop cannot, however, take up all the plant food applied to it, the roots only coming in contact with a comparatively small portion of the soil. As, therefore, part of the manure remains in the soil, it is often a good plan to apply a larger dressing of one or more of its constituents than is apparently necessary for the growth of the crop to which it is applied. The amount of the surplus thus applied must depend on the extent to which it is available as plant food, and its liability to be washed out of the soil.

Different kinds of plants vary considerably in their powers of taking up plant food. The difference between plants in this respect is largely due to differences in their habit of growth. For example, barley, which is a fibrous-rooted plant, spreading thickly through the surface of the soil, has been found at Rothamsted to return in the increase

of the crop about 60 per cent of the nitrogen applied as a top dressing of nitrate of soda, while wheat, which is, comparatively speaking, a deep rooted plant, returns only about 47 per cent of the nitrogen applied.

As a general result of crop experiments it is found that the best results are obtained by the application of nitrogenous manures to corn crops and grass, potash manures to potatoes and leguminous plants, and phosphoric acid to root crops. But it must not be understood from this that nitrogen only is required for corn, potash only for potatoes and leguminous plants, and phosphoric acid only for root crops, but that the general character of the manure applied to corn crops must be nitrogenous, and so on. For example, in so-called corn manures sold by manure merchants, the nitrogen may exist to the extent of from 4 to 6 per cent, and phosphates from 8 to 12 per cent; while in turnip manures there will be from 3 to 4 per cent of nitrogen, 20 per cent of phosphates, and 5 per cent of potash.

If this system of applying to each crop chiefly that constituent which benefits it most be followed, a rotation of manure will result coincident with the ordinary rotation of crops followed almost universally in agriculture. The advantage of this is obvious, for in the period occupied by the rotation, if the latter include representatives of the different classes of crops mentioned above, all the necessary constituents of plant food will have been applied to the soil, so that its condition will be maintained, while each separate constituent will have been applied to the crop which requires it most, and will consequently have yielded its greatest possible effect.

A marked distinction may be drawn between the effect of nitrogenous manures and those supplying the ash constituents of the plant or "cinereals," as they are called. Nitrogen applied to the soil promotes, as a rule, a strong growth of leaf, rather rank, and dark in colour, and somewhat retards the maturing and ripening of the seed. Cinereals, on the other hand, encourage the production of seed rather than leaf, and bring about an earlier ripening and maturing of the plant.

Manures.—The manures used on the farm are conveniently divided into two classes, general and special

manures. General manures are those which contain all the essential constituents of plant food, while special manures are those which are valuable chiefly for one such constituent, though sometimes more are present.

Though the general manures contain all the necessary constituents of plant growth, yet they do not necessarily contain them either in the amount or the proportions required by the plant, so that their use may not be economical. For example, if the soil contains an ample supply *of nitrogen and potash, but is deficient in phosphoric* acid, and a general manure is used, the phosphoric acid only will be of any use, while the nitrogen and potash contained in it will yield no return, and the nitrogen at least will always be liable to waste by drainage. For the economical use of manures considerable knowledge is required, in order to judge of the condition of the soil and the requirements of the crop; for it must be remembered that it is the constituent of plant food which is present in the soil in least proportion compared with the requirements of the plant which controls the extent of the crop. If there is enough of this least plentiful constituent for producing a full crop, all will be well; but if there is not sufficient, a full crop cannot be obtained, even though other constituents of plant food are present in very large quantity. These two classes of manures are further classified as follows:—

General Manures.
1. Farmyard manure.
2. Sewage and its products.
3. Seaweed.
4. Leaves and plant refuse.
5. Refuse oil-cakes.
6. Brewers' and distillers' grains.
7. Spent tanners' bark.
8. Sawdust.
9. Peat.

Nitrogenous Manures.
- Nitrates.
- Ammonium salts.
- Animal remains.
- Nitrogenous guanos.

Phosphatic Manures.
- Mineral phosphates.
- Bone phosphates.
- Phosphatic guanos.
- Phosphates treated with acids.
- Thomas phosphate.

Potash Manures.	Potash salts from sea water. Potash salts from ashes of plants. Potash salts from saline deposits.
Miscellaneous Manures.	Magnesia compounds. Soda salts. Iron salts, etc.

CHAPTER XIII

FARMYARD MANURE

THIS, the most important manure used on the farm, consists of the excrement of animals, usually mixed with a certain amount of litter. The composition of farmyard manure and its value depend on the composition of these two parts, and the proportions in which they are mixed. The excrement is divided into two parts, solid and liquid, and consists of that part of the food supplied to the animal which is not utilised by it for the production of increase and other purposes, together with the refuse matter resulting from the natural waste of the tissues. The solid excrement consists almost entirely of that part of the food which is not digested by the animal, but which has passed through its digestive system without being much acted upon, while the liquid contains those constituents of the food which have been, as it were, dissolved and taken up into the system, when, after being used in the animal economy, they are thrown out in the urine. Of the three most important constituents of plant food, the nitrogen is found to a certain extent in the solid excrement, but exists chiefly in the urine, in the form of urea, uric acid, etc., which are formed by a kind of slow combustion of the nitrogenous matter of the food in the animal's body. The potash exists in most foods in the form of organic salts, which are easily digested by the animal, and consequently most of the potash is found in the liquid excrement. The phosphoric acid, on the other hand, occurs in foods principally as insoluble mineral salts, and is therefore found in largest quantity in the dung.

As the manure made by animals consists essentially of

that part of the food which they are not able to use, its composition will in the first place depend on that of the food supplied to the animals, so that, other things being equal, the more nitrogen, potash, and phosphoric acid contained in the food the richer the manure will be. But further than this there will be a difference in the composition of the manure, according to the kind of animal consuming the food, for some utilise a larger proportion of their food for respiration, growth, fattening, or milk production, and consequently less valuable material remains in the manure. Of the most important farm animals, oxen and sheep have the least power of storing up the valuable constituents of food in their increase of body weight, and therefore the manure contains a larger amount of these constituents compared with that originally present in the food. The following table shows some of the results obtained by Lawes and Gilbert at Rothamsted, in feeding oxen, sheep, and pigs:—

TABLE XX.

Food, Increase, Manure, etc., of Fattening Animals.

Oxen.					
	Composition of dry matter of food per cent.	100 Total Dry Substance of Food Supply.			Amount of each constituent stored up for 100 of it consumed.
		In Increase.	In Manure.	In Respiration.	
Nitrogenous substance	19·6	0·8	29·1	57·3	4·1
Non-nitrogenous substance	72·9	5·2			7·2
Mineral matter	7·5	0·2	7·4	...	1·9
Total dry substance	100·0	6·2	36·5	57·3	

Sheep.					
	Composition of dry matter of food per cent.	100 Total Dry Substance of Food Supply.			Amount of each constituent stored up for 100 of it consumed.
		In *Increase.*	In *Manure.*	In Respiration.	
Nitrogenous substance .	19·4	0·8	25·1	60·1	4·2
Non-nitrogenous substance	73·6	7·0			9·4
Mineral matter . .	7·0	0·2	6·8	...	3·1
Total dry substance .	100·0	8·0	31·9	60·1	
Pigs.					
Nitrogenous substance .	12·4	1·7	14·3	65·7	13·5
Non-nitrogenous substance	85·0	15·7			18·5
Mineral matter . .	2·6	0·2	2·4	...	7·3
Total dry substance .	100·0	17·6	16·7	65·7	

From these figures it will be observed that oxen store up a smaller proportion of the food they consume in the increase than sheep, and use rather less for purposes of respiration, and therefore a slightly larger proportion of the constituents of the food is returned as manure. Pigs store up a very much larger amount of their food in the increase of their body weight than sheep, and use rather more for respiration, and therefore the proportion returned in the manure is considerably less. It must be remembered that the above figures refer only to fattening animals. Young growing stock will store up a far larger proportion of the constituents of their food, because they require material to form new growth, flesh, bone, and fat, and therefore the manure produced will be, comparatively speaking, very poor. Similarly, cows in milk will yield manure poor in composition compared with that of the food consumed, because part of

that food is utilised in the production of milk. The actual composition of the manure will depend not only on that of the food, and the kind of stock consuming it, but on the amount of water present, for the greater the amount of water the less valuable the manure will be per ton. The amount of water varies partly with the nature of the food supplied to the animal. If the food be watery, the proportion of water both in the solid and liquid excrement will be greater, and the value of the manure will consequently be less. Muntz and Girard give the following as the composition of the dung and urine of cows fed in different ways:—

TABLE XXI.

Percentage Composition of Manure from Cows fed in Various Ways.

	Mixed Food.		Watery Food.		Dry Food.	
	Dung.	Urine.	Dung.	Urine.	Dung.	Urine.
Water	80·35	...	83·00	...	79·70	...
Nitrogen	0·36	0·78	0·33	0·124	0·34	1·540
Phosphoric acid	0·15	traces	0·24	0·011	0·16	0·006
Potash	0·25	1·57	0·14	0·597	0·23	1·690

In the case of urine particularly these figures show that the presence of large quantities of water in the food causes a diminution in the proportion of the more important constituents of the manure. The proportion of water and the consequent composition of the manure also varies according to the kind of animal. Cattle produce more watery manure than sheep, and weight for weight their manure is therefore less valuable. The following analyses of Boussingault show the composition of the liquid and solid excrements, and of the mixed manure of farm animals:—

Table XXII.

Percentage amount of Various Constituents present in Manure of Farm Animals.

	Solid Excrement.	Urine. 1	Urine. 2	Mixed Excrement.
Cows.				
Water	85·90	88·30	92·10	84·30
Nitrogen	0·32	0·44	0·96	0·44
Phosphoric acid	0·14	0·06	0·00	0·09
Sheep.				
Water	57·60	86·50		67·10
Nitrogen	0·72	1·31		0·91
Phosphoric acid	0·44	0·01		0·16
Pigs.				
Water	84·00	97·90		93·80
Nitrogen	0·70	0·23		0·37
Phosphoric acid	0·62	0·04		0·28
Horses.				
Water	75·30	91·00		75·40
Nitrogen	0·55	1·48		0·74
Phosphoric acid	0·30	0·00		0·17

The kind and quantity of litter used for bedding affects the value of the manure considerably, and this influence depends, first, on its chemical composition, in so far as the litter contains nitrogen, potash, phosphoric acid, etc., which add to the amount of plant food in the soil. The following table shows the amount of the most valuable constituents in certain materials commonly used as litter :—

TABLE XXIII.

Percentages of Certain Constituents of Litter.

	Nitrogen.	Phosphoric Acid.	Potash.
Wheat straw	0·48	0·23	0·49
Barley straw	0·48	0·19	0·93
Oat straw	0·40	0·28	0·97
Pea haulm	1·04	0·38	1·07
Potato haulm (dry)	0·50	0·10	0·30
Heather	0·9	0·10	0·40
Fern	2·4	0·45	2·42
Rushes	0·4	0·35	1·67
Beech-tree leaves	0·8	0·24	0·30
Scotch fir needles	0·6	0·10	0·13
Peat	1·5	trace	0·10

As to the physical properties of litter, the most important is that of absorbing moisture and retaining plant food; indeed this absorptive power is usually of more importance than the composition of the litter. The importance of the absorptive power will be at once recognised when it is remembered that most of the nitrogen and all the potash are found in the liquid manure, and therefore can only be held in this way. The following table shows the relative absorptive power of different materials usually employed as litter:—

TABLE XXIV.

Absorptive Power of various kinds of Litter in Pounds of Water per 100 lbs.

Wheat straw	220
Barley straw	285
Oat straw	228
Pea straw	280
Bracken	212
Heather	145
Dead leaves	200
Pine needles	150 to 200
Peat	500 to 700
Sawdust	420 to 450

The composition of fresh farmyard manure is difficult to ascertain with great certainty, owing to the fact that it is almost impossible to obtain a sample for analysis that fairly represents the bulk of the manure. Dr. Voelcker gives the following as the composition of fresh farmyard manure in its natural state, and also calculated on the dry matter[1]:—

TABLE XXV.

General Composition of Fresh Long Dung (composed of Horse, Cow, and Pig Dung).

	In natural state.	Calculated dry.
Water	66·17	...
*Soluble organic matter	2·48	7·33
Soluble inorganic matter	1·54	4·55
†Insoluble organic matter	25·76	76·15
Insoluble inorganic matter	4·05	11·97
	100·00	100·00
*Containing nitrogen	·149	·44
Equal to ammonia	·181	·53
†Containing nitrogen	·494	·146
Equal to ammonia	·599	·177
Total percentage of nitrogen	·643	1·90
Equal to ammonia	·780	2·30

From these figures it will be seen that in the natural state only 4·02 per cent of the solid matter of the manure is soluble, while 29·81 is insoluble, and therefore of little immediate use to the plant. In the same investigation it was also found that very little nitrogen exists in the form of ammonia, either free or in a state of combination. In the manure, the composition of which is given above, the percentage of ammonia in these two forms was as follows:—

[1] *Journal R.A.S.E.*, vol. xvii.

TABLE XXVI.

Percentage of Ammonia in Long Dung.

	In natural state.	Calculated dry.
Percentage of free ammonia . .	·034	·10
Percentage of ammonia in the state of salts	·088	·26

Of the other compounds of nitrogen very few are soluble. It is somewhat remarkable that among the mineral constituents of the manure, a considerable amount of phosphate of lime exists in a soluble form, this being 19½ per cent of the whole amount of the soluble mineral matter in the manure, while it forms only 9½ per cent of the insoluble ash. The most important of the soluble mineral substances is potash.

When farmyard manure is kept for any length of time fermentation takes place, resulting in a loss of weight and a change in its composition. The change takes place principally in the organic matter. The two main results of this fermentation are, first, a change in the condition of the plant food, rendering it more valuable for the use of the plant, and, secondly, changes liable to cause loss of valuable matter, particularly of nitrogen.

The rate of change differs greatly in the liquid and solid excrements. In the urine, when perfectly fresh, almost all the nitrogen exists in the form of organic compounds, only about 0·4 per cent of the total nitrogen being in the form of ammonia; but fermentation begins almost directly, in the process of which ammonia is formed. On the other hand, in the solid excrement fermentation is comparatively very slow, and but little ammonia is formed. Just as in the case of all other fermentations, the rapidity with which it takes place is controlled to a great extent by the temperature. Müntz and Girard give the following as the percentage of the total nitrogen which is in the form of ammonia in the urine of cows and horses kept for two months at different temperatures:—

TABLE XXVII.

Percentage of Total Nitrogen existing as Ammonia in Urine after Fermentation.

Animal Producing.	Mean Temperature.			
	Very low.	12° C.	20° C.	38° C.
Cow . . .	33	83	90	95
Horse . . .	45	70	80	90

When the manure is put into a heap further actions take place; the heap becomes hot, owing to rapid fermentation, and more organic matter disappears. This is due to a kind of slow combustion, in the process of which the carbon contained in the manure forms carbon dioxide, and, as one would expect, the rate of this combustion depends on the freedom with which the air can gain access to the manure; the more consolidated the heap the slower the combustion will be. The texture and natural character of the manure also affects the rate of fermentation, and that of horses and sheep heats most rapidly, while that of cows and pigs heats comparatively slowly. Another action is the formation of certain organic acids known as humic acid, ulmic acid, etc., which are produced by the decomposition of carbonaceous material. We see, then, that in the fermentation an alkaline substance, ammonia, is produced, as well as the acids just mentioned, and, as is the case whenever acids and alkali come into contact, combination takes place, and salts of ammonia are formed, which are generally of a stable character, and are not liable to loss by volatilisation. An important exception, however, is ammonium carbonate, formed by the combination of ammonia with carbon dioxide, and produced in largest quantity when fermentation is most rapid. Whether volatile or not, it must be remembered, however, that these ammonium compounds are very soluble, and that there is still risk of loss by drainage from the heap. Many other compounds are

formed during the fermentation of the manure, for example, marsh gas, but these are of minor importance.

The chief action in fermentation, then, is to burn away the carbon of the manure, and therefore the result is that the fertilising substances are concentrated. Considering the dry material only, the composition of the manure will be very much more valuable, though often on the farm the amount of water will be greater in rotten manure than in fresh, owing to rain falling on it while fermenting, and therefore the amount of the valuable constituents per ton will be rather less. Voelcker gives the following percentages of valuable constituents in fresh and rotten manure respectively, calculated on the dry matter:—

TABLE XXVIII.

Amount of Certain Constituents of Farmyard Manure per cent of the Dry Material.

	Fresh.	Rotten.
Phosphoric acid	0·938	1·1829
Potash	1·990	1·996
Total nitrogen	1·900	2·470
Ammonia, in free state	0·100	0·189
Ammonia, in form of salts	0·260	0·232

It will be seen that each one of the valuable constituents of the manure exists in larger proportion after the process of fermentation, excepting only ammonia in the form of salts. The total ammonia present, however, free and in the form of salts, is greater in the rotten manure. The fact that the amount of potash is practically the same in both fresh and rotten manure will be accounted for by its solubility from the time of the first formation of the manure, in consequence of which it is exposed to loss by drainage during the whole process of fermentation.

The loss of weight occurring during fermentation varies considerably, according to the conditions under which the manure is kept. In experiments tried under various con-

ditions, Voelcker found the following percentage of loss in the periods named :—

TABLE XXIX.

Loss of Weight per cent of Farmyard Manure on keeping.

How kept.	178 Days.	293 Days.	377 Days.
In heap exposed . .	28·6	29·7	30·4
In heap under cover .	50·4	60·0	62·1
Spread and exposed .	13·4	38·7	42·4

The facts that we have considered show that the loss of valuable material may take place in two ways, first, by volatilisation; secondly, by drainage, and both these causes must be borne in mind in the management of manure. In order to obtain the best results, farmyard manure should be protected, and if possible both made and kept under cover.

Covered yards are superior to open ones for making manure, owing to the protection they give. The gain in the money value of the manure made by fatting cattle, and the gain in the well-doing of the stock kept has been estimated as follows per beast housed per annum [1] :—

	£	s.	d.
Economy of food, superior health and well-doing of stock, estimated per head	£1	2	6
Superiority of manure, estimated per head	0	14	0
Economy in application of same, estimated per head .	0	5	4
Saving of litter (straw) to be used as food, 1½ tons per head (at consuming value)	1	10	0
	£3	11	10

The first item in the above table is considerably less than the estimate given by many authorities. The advantage to the animal is owing to the fact that, being kept warm in winter, less food is required to keep up the heat of the body, and the animal is able to use so much more of the food it consumes for the production of meat or milk.

[1] W. J. Moscrop, *Journal R.A.S.E.*, vol. i. T.S.

As to the superiority of the manure produced considerable difference of opinion is found, but it is frequently estimated that manure made under cover is worth about twice as much as that made in open yards. In the above table it is taken as being 50 per cent more valuable. The economy in the application of the manure is calculated on the supposition that a medium-sized animal will produce about eight tons of manure during the winter months, whereas about half as much again would be produced in open yards. *There is, therefore, an economy to the amount stated in the* labour of handling and applying the manure.

The gain estimated above presupposes, however, careful management of the manure in all its stages. If it is allowed to get too dry, the air will have free access to it and fermentation will proceed more rapidly in consequence. To avoid this it is necessary to supply stock kept under cover with only small quantities of litter at a time, just enough to keep them dry. In this way it is well trampled in and consolidated. If by any accident the manure becomes too dry it should be moistened with liquid manure if possible, or even with water. Similarly, manure made in boxes must be kept solid, and rather moist, though if the boxes are well made, so as to retain the whole of the liquid part of the manure, there will be less chance of its becoming too dry than there is in a covered yard. Manure made in stalls, when removed from the houses, should, if possible, be put into a manure shed, when every endeavour should be made to keep the liquid part of it mixed with the solid. Some drainage from the heap is, of course, certain to take place, and this should be carefully collected in a liquid manure tank, which should also be arranged to receive the drainage from the yards and buildings, though not rain water. It is a good plan, though one often neglected, to pump the liquid manure from the tank over a heap in the shed at intervals, in this way keeping the heap cool and moist, and checking too rapid fermentation. A further point necessary to be observed for controlling the fermentation is that the manure produced by different kinds of stock should be mixed together, so that the comparatively cool manure produced by cattle and pigs may serve to moderate the more rapid fermentation natural to horse manure.

As a matter of convenience farmyard manure is generally taken out from the yards and buildings and put up into heaps near the field to which it is to be applied. This is done at any convenient time in the year, and serves to economise labour at the more busy seasons. These heaps should be protected as much as possible from loss by drainage, which may be done by placing layers of absorbent material amongst the manure, and by putting at the bottom of the heap a thick layer of some such material as burnt clay, ashes, etc. A covering of earth is also frequently given, which serves partly to keep out rain water, and also to prevent the ammonia being given off from the surface of the heap. In the same way a rough thatch is sometimes put over the heap to protect it from the weather. Another plan adopted for saving the drainage from heaps is to make them in a kind of basin, hollowed out and puddled with clay so as to be water-tight. At the bottom a thick layer of some absorbent material is put, which serves to suck up the liquid draining from the heap. In order to check the fermentation in these large heaps, it is common for the carts to drive on to the top of them before unloading. In this way, by the constant passage of horses and carts over the heap while it is being built, it is consolidated, and fermentation is consequently slow.

Manure heaps are very often turned by hand, in order to give the manure a better texture for subsequent handling, spreading on the land, etc., but this should only be done if fermentation is very slow and needs to be encouraged, or when the greater part of the fermentation is over. In any case, in turning the heap a loss of ammonia will probably take place.

Liquid manure collected into a tank ferments rather rapidly, in the way that has been already described in connection with urine. Ammonia is formed and is of course liable to be lost, owing to its volatile properties. To avoid this, gypsum, a form of sulphate of lime, or sulphuric acid is sometimes added, with the object of "fixing," as it is called, the ammonia, that is, converting it into a non-volatile substance—sulphate of ammonia.

The different ways of storing manure have different effects upon its composition. Table XXX. shows the gain or loss of the various constituents of manure kept in various

ways, as determined by Dr. Voelcker. The composition of the manure when fresh has been given in Table XXV., p. 113.

TABLE XXX.

Percentage of Gain or Loss of Farmyard Manure and of its Constituents when kept in Various Ways.

	Kept 6 Months.		Kept 9 Months.		Kept 12 Months.	
	Gain.	Loss.	Gain.	Loss.	Gain.	Loss.
1. MANURE IN HEAP, EXPOSED.						
Total weight	...	28·61	...	29·77	...	30·45
Water	...	19·09	...	13·12	...	14·19
*Soluble organic matter	0·56	...	...	0·40	...	0·57
Soluble mineral matter	0·49	...	...	0·16	...	0·24
†Insoluble organic matter	...	12·03	...	17·18	...	18·17
Insoluble mineral matter	1·4[illegible]	...	1·14	...	3·05	...
*Containing nitrogen	0·005	...	...	0·016	...	0·020
†Containing nitrogen	...	0·068	...	0·160	...	0·160
Ammonia in free state	...	0·028	...	0·026	...	0·029
Ammonia in form of salts	...	0·027	...	0·060	...	0·059
2. MANURE UNDER SHED.						
Total weight	...	50·49	...	60·19	...	62·09
Water	...	38·00	...	48·88	...	50·35
*Soluble organic matter	...	0·18	...	0·83	...	0·44
Soluble mineral matter	0·13	...	...	0·32	0·14	...
†Insoluble organic matter	...	13·16	...	15·40	...	15·26
Insoluble mineral matter	0·73	...	5·26	...	2·85	...
*Containing nitrogen	...	0·014	...	0·012	0·012	...
†Containing nitrogen	...	0·036	...	0·092	...	0·078
Ammonia in free state	...	0·006	...	0·027	...	0·026
Ammonia in form of salts	...	0·030	...	0·016	...	0·032
3. MANURE SPREAD AND EXPOSED.						
Total weight	...	13·49	...	38·74	...	42·49
Water	3·02	...	...	23·22	...	28·46
*Soluble organic matter	...	1·17	...	2·18	...	2·24
Soluble mineral matter	...	0·66	...	1·14	...	1·20
†Insoluble organic matter	...	15·85	...	19·29	...	20·05
Insoluble mineral matter	1·44	...	7·11	...	9·40	...
*Containing nitrogen	...	0·12	...	0·16	...	0·18
†Containing nitrogen	0·018	...	...	0·16	...	0·16
Ammonia in free state	...	0·024	...	0·025	...	0·033
Ammonia in form of salts	...	0·050	...	0·050	...	0·070

This shows the great advantage of keeping manure under cover, for though the bulk and weight diminish considerably under cover, there is much less loss of the valuable constituents of the manure. Roughly speaking, in the case of manure kept under cover there was a loss in the year of about one-tenth of the nitrogen originally present. In the exposed heap the loss was equal to one-third of the original amount, and when spread and exposed to the weather the loss was about two thirds.

With regard to the application of farmyard manure to the land, the time of doing this and the state in which the manure should be, depend upon the conditions, particularly upon the kind of soil and of crop. As a general rule it may be said that fresh manure, or long dung, as it is often called, is better for heavy soils; but if it is used it must be applied some time before the plant requires it, that is, in the autumn. In this way time is allowed for the decomposition of the manure in the soil, while, owing to the power that heavy soils have of retaining plant food, there is little chance of its being wasted. In the case of sandy land, on the other hand, if the manure were applied in autumn, as its constituents became soluble they would be washed away to a great extent by the winter rains and so wasted. On such soils, therefore, the manure must be applied just when it is required, that is, shortly before spring growth commences. This being so, there is of course no opportunity for change to take place in the state of the manure in the soil, and it must therefore be in a rotten condition before it is applied. *From a purely chemical point of view*, taking into account only the composition of the manure, the least loss would probably occur when the manure was carried direct on to the land as soon as made, but this system would seldom be convenient or possible. The crop also has to be considered, because in the case of a quick-growing plant having only a short time in which to obtain its necessary food, that food must be supplied to it in an available form, and therefore if farmyard manure be employed it must be well rotted. Slow-growing crops, on the other hand, require a continuous supply of plant food for a considerable time, and therefore fresh manure is more suitable. The immediate effect of an application of fresh manure is

principally to supply potash to the plant, for, before fermentation takes place, potash exists in an available form to a greater extent than the other valuable manurial constituents. In rotten manure, on the other hand, much of the nitrogen has become available, and it is this constituent which has the greatest effect.

On the question of whether manure should be left spread on the surface of the land or ploughed in at once, there is a considerable difference of opinion. From a chemical point of view the former plan is probably the more advantageous, for when spread for some time on the surface the soluble plant food contained in the manure is washed into the soil and evenly distributed through it, and in the case of most soils there is sufficient retentive power to prevent loss of valuable material. The important effect of the manure on the physical texture of the soil, either in the case of very strong land or very light, is at least partially lost by this plan, heavy soils being better broken up in texture by ploughing the manure in at once.

The quantity of farmyard manure applied varies in different districts and under different circumstances from about 10 tons per acre or less up to 25 or 30 tons per acre, or sometimes more. When applied to grass lands the dressings are usually rather light. On arable land farmyard manure is largely employed for the growth of turnips or other root crops, but is also applied to wheat, beans, clovers, and indeed almost all the common farm crops.

Besides its action as plant food, the physical effects of farmyard manure are important. These are chiefly the result of the large quantity of organic matter it contains, which affects the power of the soil to absorb and retain moisture and manurial matter. As to moisture the point is well illustrated by the experiments in the continuous growth of wheat carried out at Rothamsted. There it was found that the soil of the plot manured every year with farmyard manure has been so altered in its power of holding water that the drains seldom or never run, though those of the plots not manured or manured only with mineral substances run as usual in time of rain.

In districts where little or no corn is grown, and litter is consequently scarce, some system of applying manure in

its natural state has to be adopted. In some districts the plan of "blonging" is followed, in which the manure is mixed with several times its own weight of water in a large tank, and is afterwards distributed over the land by means of gravitation, or more commonly by a liquid manure cart. Even distribution of the manure is thus obtained, but there is more labour in its application and a greater chance of waste of the valuable constituents. In any case, if little or no litter is used, greater care must be taken of the liquid part of the manure, which is more easily wasted, because there is nothing to absorb it.

Folding sheep is another way of applying the excrement of farm animals to the surface of the land. The system of folding sheep on roots and other forage crops is most common, and in this case the land is enriched by the addition of dry food to the ration the sheep are given, and also by the organic matter which the crop has stored up during its growth. One important point to notice is that the manure is applied to the soil with the least possible loss. Occasionally another system of folding is adopted, namely, that of keeping the sheep on poor arable land during the night, the food being supplied during the day. In this way the flock becomes the carrier of manure from the land on which it is fed to the fallows on which it is folded, and the enrichment of the one takes place at the expense of the other. A good dressing of manure applied in this way is given by keeping on the land 1200 to 1500 sheep per acre for one night. The converse of this plan is sometimes adopted, though it does not come strictly under the head of folding. The sheep are then used as carriers of manure to the inaccessible parts of the farm, to which the expense of carting ordinary manure would be too great.

CHAPTER XIV

SEWAGE AND OTHER GENERAL MANURES

Sewage.—The demand for the proper purification of sewage is becoming continually greater, and it is also felt to be a matter of importance that the fertilising material contained in the sewage should be utilised in some way for the production of food for man or for farm animals. The amount of this valuable material is not inconsiderable, as will be seen by reference to the following table:—

TABLE XXXI.

Composition of Sewage from Various Sources in Parts per 100,000.

No.	In 100,000 Parts.							Suspended Matter.		
	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Mineral.	Organic.	Total.
1	66·5	5·137	2·375	6·050	0	7·357	...	15·18	18·84	34·32
2	65·3	2·596	1·715	4·000	0	5·010	8·6	18·48	27·80	46·28
3	107·5	2·017	·809	2·083	0	2·524	...	10·50	11·62	22·12
4	41·2	2·565	1·134	3·635	0	4·128	4·0	·84	4·10	4·94
5	76·1	2·256	1·301	3·100	0	3·854	10·9	8·16	13·68	21·84
6	83·5	4·355	2·890	5·971	0	7·807	11·0	96·24	56·28	152·52
7	62·0	2·215	1·516	·380	0	1·829	...	23·18	11·22	34·40
8	47·6	2·874	1·046	1·730	0	2·471	9·0	4·72	5·44	10·16
9	42·0	2·985	1·843	6·430	0	7·138	...	6·78	14·58	21·36
10	72·6	4·834	1·088	3·475	0	3·950	8·3	9·24	16·16	25·40
11	71·2	4·968	1·495	3·492	0	4·371	10·6	11·84	19·24	31·08
12	62·2	6·106	3·613	9·510	0	11·445	13·3	11·32	28·08	39·40

Of the above, Nos. 1 and 2 were obtained from London, 3 from Leicester, 4 from Croydon, 5 from Bedford, 6 from Leamington, 7 from Manchester, 8 from Macclesfield, 9 from Bolton, 10 from Blackburn, 11 from Chorley, and 12 from Edinburgh.

The actual quantity of fertilising matter produced by any town depends of course on the number of its population. It has been calculated by various authorities that the amount of ammonia produced per unit of population per annum is from 10 to 15¾ lbs., and that of phosphates about 5½ lbs.

The difficulty in utilising sewage material is that the bulk is so very large compared with its value. The quantity of water and altogether useless solid matter dilutes the nitrogen and other fertilising material to such an extent that the value per ton at the highest computation cannot be taken at more than from 1d. to 2d. A further difficulty is due to the fact that the supply of sewage is continuous throughout the whole year, whereas, for application to the land at any rate, far larger quantities are required during the summer season, when growth is taking place, than during the winter, when growth is at a minimum. The first cost of laying out the land is also frequently a difficulty, as it necessitates a heavy charge on the land.

The usual method of utilising sewage is by some simple system of irrigation, as, for instance, the bed-work or catch-work system, or sometimes by intermittent filtration, in which the crops are grown on rather high ridges and the sewage is applied to the furrows between them. In this way flooding with sewage can take place any time during the growth of the crop, and in consequence a smaller area is required for dealing with any given quantity of sewage, and there is less risk of injuring the crops by contamination through contact with the sewage.

The system of sewage irrigation is chiefly applied to market gardens, and the growth of forage crops. An example of the cropping of a sewage farm and the amount of sewage applied to the different crops in one year is given in the following table[1] :—

[1] *Journal R.A.S.E.*, vol. xvi. S.S.

Table XXXII.

Quantity of Sewage supplied to Various Crops on the Leamington Sewage Farm, 1877.

Acreage. A.	R.	P.	Crop.	Number of Dressings.	Total Amount. Tons.
33	0	0	7 acres Italian rye grass and 26 acres permanent pasture . . .	29	393,643
8	0	0	Italian rye grass . . .	26	85,468
8	2	0	Do. . . .	27	93,979
4	0	0	Do. . . .	36	58,510
8	0	0	Do. . . .	14	45,938
10	1	34	Italian rye grass, strawberries, and rhubarb .	18	72,128
7	0	0	Fallow for oats . . .	20	56,378
5	0	12	Mangold	15	30,913
4	1	0	Cabbage	5	16,333
5	2	0	Do.	4	9,481
14	1	14	Mangold	13	89,568
7	0	0	Do.	23	58,664
3	0	0	Turnips	2	3,133
11	0	36	Italian rye grass . . .	32	143,638
2	0	0	Savoys	2	2,172
20	0	0	Fallow for turnips . .	5	42,000
10	0	0	Italian rye grass . . .	5	21,000
13	1	17	Do. . . .	2	11,268
5	0	4	Parsnips and cabbage . .	10	45,000
10	3	24	Permanent pasture . .	4	17,500
9	1	29	Fallow for turnips . .	4	17,500
					1,314,214

This table gives an idea of the amount of sewage which may be supplied with advantage to the different kinds of crops. It will be seen that Italian rye grass has the power of utilising the greatest quantity.

The texture of the soil employed for sewage farming is a very important matter, a rather porous soil being most suitable for the purpose. The sewage filters through heavy soils too slowly, and the soil becomes clogged, as it were, and suffers for want of aeration. The following is taken from the report of a sewage farm competition of the Royal Agricultural Society in 1879:—

Statement of the Physical Properties of the Soils on the undermentioned Sewage Farms.

No.	Name of Place.	Description of Soil.	Percentage of Water by weight Soil will absorb.
1	Aldershot . . .	Light sandy . .	36·2
2	Bedford . . .	Do. . . .	34·7
3	Do. . . .	Loamy . . .	43·5
4	Birmingham . .	Light soil, containing peat and other organic matter. .	79·7
5	Do. . . .	Stiff land, clay . .	57·6
6	Croydon (Beddington)	Light, peaty . .	103·0
7	Do. . .	Subsoil below last sample, yellow marl	25·9
8	Do. . .	Gravelly surface soil .	48·5
9	Do. . .	Do. . .	49·7
10	Do. . .	Subsoil, open gravel from below last sample . . .	13·1
11	Do. . .	Gravelly soil (dark colour), containing organic matter and fine roots . .	65·9
12	Do. . .	Open gravel subsoil from under last sample . . .	9·4
13	Doncaster . . .	Light sandy soil .	24·2
14	Do. . . .	Soil from mangold field	28·8
15	Do. . . .	Stiff soil (clay) . .	47·3
16	Guisborough . .	Stiff soil . . .	54·3
17	Do. . . .	Do. . . .	49·3
18	Leamington . .	Light sandy soil .	23·4
19	Do. . . .	Stiff soil . . .	44·9
20	Do. . . .	Heavy soil (clay) .	56·6
21	Reading . . .	Light soil . . .	40·2
22	Do. . . .	Subsoil, one foot deep below last sample	32·7
23	Do. . . .	Stiff soil . . .	48·3
24	Do. . . .	Subsoil, one foot deep below last sample	46·2
25	Wrexham . . .	Sandy and peaty, containing much organic matter (Stanstey Meadow)	61·5
26	Do. . . .	Sandy and peaty, containing much organic matter — from market garden	80·0

From this it will be seen that in most cases the soil of the competing farms was that of a light sandy or peaty character.

Sewage is also treated by a number of chemical processes of precipitation, for instance the A B C, the phosphate of alumina, the sulphate of alumina, and Whitthread's processes. In all these the object is to obtain a concentrated, comparatively dry "sludge," and a clear, inoffensive liquid. The sludge in some cases is then manufactured into a more or less dry manure, but the cost of manufacture is often greater than the value of the manure produced.

Another system is that of simply drying the mixed excreta to form what is called "poudrette." The water is got rid of in the process, but there is great loss of nitrogen, which is given off in the form of ammonia, and potash is lost in the effluent water. This system is followed more in France than in this country. Aubin gives the following as the composition of different samples of poudrette obtained in Paris:—

TABLE XXXIV.

Percentage of Valuable Constituents of Poudrette.

Sample No.	Nitrogen.	Phosphoric Acid.	Potash.
1	1·65	2·62	0·67
2	1·83	3·76	1·96
3	1·88	2·12	0·90
4	2·09	4·60	...
5	1·10	3·32	...
6	1·81	2·76	0·57
7	0·32	1·34	1·80
8	0·43	...	...
9	1·78	3·83	...

A somewhat similar result is obtained by the use of earth closets, which are largely employed in country districts. Dry earth or ashes are here used as a deodoriser, and are afterwards dried so that they may be used several times. A considerable loss of nitrogen takes place under this system,

and the produce contains so large a proportion of earth that it has little value as a fertiliser. Voelcker gives the following analysis of earth-closet manure[1] :—

TABLE XXXV.

Composition of Earth and three Samples of Earth-Closet Manure in Dry State (dried at 212° Fahr.).

	No. 1. Earth for use in Closets.	No. 2. Earth once used in Closets.	No. 3. Earth twice used in Closets.	No. 4. Earth thrice used in Closets.
*Organic matter and water of combination . . .	9·88	9·79	11·53	12·22
Oxide of iron and alumina . .	12·95	16·15	14·11	12·48
Phosphoric acid .	·18	·25	·44	·51
Carbonate of lime .	2·21	2·25	2·13	2·11
Magnesia . . .	1·44	2·63	·77	·90
Alkalies and loss in analysis . .	1·35		·72	·74
Insoluble silicious matter (clay and sand) . . .	71·99	68·93	70·30	71·01
	100·00	100·00	100·00	100·00
*Containing nitrogen	·31	·37	·42	·51
Equal to ammonia	·37	·45	·51	·62

It will be seen that even after using three times the manure is not richer in valuable constituents than a rather fertile soil, and consequently, though it may be used with advantage for immediate application to the soil, it will not bear cartage to any distance nor the expenditure of much labour upon it.

Seaweed.—Along the coasts, and particularly in the west of the country, seaweed is used a good deal as a manure. Its composition varies with the species, and in some districts "red tangle"[2] is in particular preferred to other kinds. The

[1] *Journal R.A.S.E.*, vol. viii. S.S.

proportion of water in it also varies considerably, and of course affects the proportion of the fertilising constituents. Usually seaweed will contain about 80 per cent of water, 0·2 to 0·4 per cent of nitrogen, and sometimes more; of potash, 0·4 to 0·5, and of phosphoric acid about 0·3. The composition of seaweed is generally richer when it is cut than when it is washed up by storm, the reason being that what is washed up naturally is generally old, matured seaweed, which, just like mature specimens of other plants, *is inferior in composition to that which is young and growing freely.*

Seaweed is chiefly used for the growth of potatoes, either applied direct to the crop, or better, applied to the previous crop. It may either be spread on land in its fresh condition or after it has been made into a compost, that is, allowed to remain in a heap for some time, mixed with soil or lime and any available vegetable refuse.

In its effects on the soil seaweed is very similar to farm manure, though on the average it is scarcely so valuable.

Leaves and Plant Refuse.—The composition of leaves varies in the same way as that of seaweed, depending on the age of the leaf and its stage of growth. Young leaves and shoots are richer in the valuable manurial constituents than dead leaves which have fallen from the plant in the ordinary way. The following table shows the composition of the dry matter of leaves of some of the common plants and trees:—

TABLE XXXVI.

Percentage of certain Constituents in the Dry Matter of Leaves of Various Plants.

	Nitrogen.	Potash.	Phosphoric Acid.
Turnip	3·67	2·86	0·71
Swede	3·33	2·33	0·66
Mangold	4·48	3·62	0·87
Carrot	2·93	1·33	0·95
Potato (haulms)	2·29	0·37	1·08
Beech	0·94	0·35	0·28
Oak	0·94	0·29	0·40
Fir	0·95	0·15	0·38
Scotch pine	0·92	0·15	0·11

Generally speaking, amongst the leaves of common trees the largest amount of potash is contained in those of the beech, the elm, the oak, and the maple, while the most phosphoric acid exists in those of the oak and the ash. The leaves of root crops are usually ploughed in whilst fresh, but when the leaves of trees are used as a manure they are generally composted first, or sometimes used as litter for stock.

The root residues of the crops are rather similar to the leaves in their action on the soil and on the plant, that is, they return to the soil part of the plant food taken from it by the crop, and also add to the amount of humus.

Green Manuring.—This consists of growing a crop and afterwards ploughing it in. At first sight it seems that little enrichment of the soil can take place by such a plan. But there is in all cases a considerable gain in organic matter, which the plant has obtained from the air, and the plant food which it has obtained from the soil is returned to the land. In the majority of plants this is the only action, but in the case of the leguminous plants, clovers and others of the same kind, there is a marked addition to the amount of nitrogen in the soil, for these plants, it will be remembered, obtain nitrogen indirectly from the air. The ploughing in of the crop is best done in rather warm and moderately dry weather, as the decay of the vegetable matter takes place most rapidly under these conditions. The crops usually employed for green manuring are those which are rapid in their growth and not of much value for feeding purposes, such as mustard, buckwheat, lupins and spurry, and less frequently vetches and rape.

Perhaps the most important action of a crop grown in this way is that it prevents a waste of nitrogen in the drainage water, particularly in winter. The growing plant takes up the nitrates formed in the soil and fixes them in its own tissues, and the nitrogen is afterwards returned to the soil when the crop is ploughed in. It has been found that land under a crop invariably loses less nitrogen in the drainage water than when bare. For example, the amount of nitrates in the drainage water from permanent grass land is much less per annum than that from the ordinary arable soil. Green manuring is therefore most important on light

sandy lands, from which the nitrogen is most likely to be lost, and where there is the greatest advantage from the addition of humus. On very heavy clays, however, it is also valuable by improving the physical texture of the soil, opening it up and making it lighter and more pervious.

Sawdust.—This has sometimes been recommended as a manure, but is of very little fertilising value. In the case of the hard woods, sawdust usually contains about 0·5 per cent of nitrogen, while in the conifers the average is about 0·2 to 0·3 per cent. It has been stated that, though sawdust contains little fertilising material, yet it produces considerable effect by the solvent action of the carbon dioxide given off during its decomposition; but at Rothamsted, in the experiments on meadow land, it was found that 2000 lbs. of sawdust per acre yielded on the average less hay than when no manure at all was applied, and when sawdust was mixed with other manures and applied to the land the produce was in different instances either very slightly greater or rather less than that of similar plots on which no sawdust had been used.

Peat.—This is chiefly valuable for the nitrogen it contains, though the quantity present is usually not very great. The nitrogen exists in the form of organic compounds, which only decompose slowly, and consequently are of little value to the plant. As manure, therefore, peat is very slow in its action, and is usually employed as litter for stock before application to the land, and for that purpose has considerable value, owing to its absorbent properties and its consequent power of retaining liquid manure.

Refuse Oil-cake.—The oil-cakes are the residues obtained in the process of crushing various seeds for the extraction of oil. They are, generally speaking, rich in nitrogen, and their value chiefly depends on the amount of this element present, but considerable quantities of phosphoric acid and potash are also present, and increase the value of the oil-cake as manure. The more perfectly the oil has been extracted from the seeds the better the cake is for manurial purposes, because the oil is of no fertilising value, and by its extraction the proportion of other and more valuable constituents is increased. Besides this, oil acts to some extent as a preservative, preventing the decomposition of

the other constituents of the cake, so that the smaller its proportion the more rapidly does the plant food become available. The following table shows the composition of various oil-cakes :—

TABLE XXXVII.

Manurial Constituents of Oil cakes.

	Nitrogen.	Phosphoric Acid.	Potash.	Oil.
	Per cent.	Per cent	Per cent.	Per cent.
Earth-nut cake, undecorticated	5·37	0·59	...	8·12
,, decorticated .	7·51	1·53	1·50	7·90
Camelina cake . . .	4·93	1·87	...	9·22
Hemp cake	4·91	1·90	...	6·20
Cotton cake, undecorticated .	3·90	1·21	1·65	6·18
,, decorticated .	6·55	3·05	1·58	16·40
Linseed cake	5·04	2·15	1·29	9·90
Mustard cake . . .	5·81	2·05	...	11·80
Rape cake	4·63	1·65	1·46	...
Niger cake	5·00	1·72	...	5·80
Palm-nut cake . . .	2·40	1·20	0·55	13·50
Poppy cake	5·88	2·53	1·98	10·50
Castor cake	3·67	1·62	1·12	8·25
Sesamum cake . . .	6·34	2·03	1·45	9·70

In any case the nitrogen takes some time to become available for the plant's use, but does so most quickly in wet seasons, and consequently all the cakes give better results in such years than in dry seasons. The best results are usually obtained on sandy or on very stiff soils, in both of which cases the physical properties of the manure as well as the plant food it contains are of great value.

Many of the cakes mentioned in the above table are too expensive for general use as manure, and are more commonly applied for feeding purposes for stock, the residue not utilised by the stock eventually finding its way on to the land in the form of farmyard manure. The cake most commonly used in its original condition is rape cake, which is comparatively low-priced, and is not much relished by

stock, owing to its bitter taste. It sometimes happens that damaged lots of other cakes may be obtained in the market at such a price as will render them economical and useful manures.

Brewers' and Distillers' Grains.—These usually contain very large quantities of water, frequently 75 per cent and upwards, and consequently are of large bulk and will not bear much expenditure in carriage or labour. In this case, again, nitrogen is the chief element of value, and usually it exists only in quantities equal to about 0·75 per cent. Grains are only used to any extent as manure in the immediate neighbourhood of large breweries or distilleries.

Spent Bark from Tanneries.—This contains little of value except a small quantity of nitrogen, which, moreover, is very slow in its action. When used at all, bark is better made into a compost with soil or lime.

CHAPTER XV

NITROGENOUS MANURES

THE special manures, as already stated, are conveniently divided into three main groups, nitrogenous, phosphatic, and potassic manures, according to their composition. There are, however, many substances holding an intermediate position between these groups, for instance the guanos, which contain both nitrogen and phosphates, often in considerable quantities; and nitrate of potash, which is both a nitrogenous and a potassic manure.

The action of nitrogenous manures on almost all kinds of plants is to increase their luxuriance in a very marked manner. In addition to the increase in the amount of leaf the whole plant is of a much darker green colour, that is, it contains a larger proportion of chlorophyll, the colouring matter, which, apparently, is so important in enabling the plant to take up carbon from the air. Accordingly, if a plant, supplied with other kinds of plant food, be given a fair proportion of nitrogenous manure, it will be able to produce a much larger quantity of carbonaceous material than if the nitrogen were not added. If there is not a full supply of mineral matter in addition to the nitrogen, the plant will not be able to assimilate carbon, in spite of the large amount of chlorophyll it contains. The connection between the nitrogen accumulation, chlorophyll formation, and carbon assimilation is shown by the following figures of Lawes and Gilbert :—

TABLE XXXVIII.

Relation of Carbon Assimilation to Nitrogen Accumulation and to Chlorophyll formed.

	Nitrogen percentage in Dry Matter.[1]	Relative Amount of Chlorophyll.	Carbon per Acre per Annum = lbs.	
			Actual.	Difference.
Hay.				
Gramineæ . .	1·190	0·77	...	...
Leguminosæ . .	2·478	2·40	...	...
Wheat.				
Plot 10a . .	(1·227)	2·00	1398	824
Plot 7 . . .	(0·566)	1·00	2222	...
Barley.				
Plot 1a . . .	(1·474)	3·20	1403	685
Plot 4a . . .	(0·792)	1·46	2018	...

[1] The figures given in parentheses are on the substance partially dried, but not fully dried, at 100° C.

Plots 10a of wheat and 1a of barley were manured with salts of ammonia only, and plots 7 of wheat and 4a of barley with ammonium and a mixed mineral manure. It must be noticed that the amounts of chlorophyll given in the table are relative, not actual, and only show the relative amounts for each pair of experiments, not between individuals of different pairs. These results show very clearly that when the percentage of nitrogen in the crop is high, the amount of chlorophyll is also increased; but the wheat and barley experiments also show that in spite of this the plant is not well able to assimilate carbon unless the mineral constituents of plant food are supplied to it in addition to nitrogen. The amount of carbon and of carbohydrates formed in various crops as the result of nitrogenous manuring is shown by the following summary of results obtained at Rothamsted by Lawes and Gilbert :—

TABLE XXXIX.

Estimates of the Yield and Gain of Carbon, and of the Gain of Carbohydrates, per Acre per Annum, in various Experimental Crops grown at Rothamsted.

	Carbon. Actual.	Carbon. Gain.	Carbohydrates. Actual Gain.	Carbohydrates. For 1 of Nitrogen in Manure.
	lbs.	lbs.	lbs.	lbs.
WHEAT, 20 YEARS, 1852-1871.				
Mineral manure	988	...	...	...
Mineral manure and 43 lbs. nitrogen (Nitrogen as ammonia)	1590	602	1240	28·8
Mineral manure and 86 lbs. nitrogen (Nitrogen as ammonia)	2222	1234	2550	29·7
Mineral manure and 86 lbs. nitrogen as nitrate	2500	1512	3140	36·5
BARLEY, 20 YEARS, 1852-1871.				
Mineral manure	1138	...	...	...
Mineral manure and 43 lbs. nitrogen as ammonia	2088	950	1992	46·3
SUGAR-BEET, 3 YEARS, 1871-1873.				
Mineral manure	1123	...	...	...
Mineral manure and 86 lbs. nitrogen as ammonia	2600	1477	3188	37·1
Mineral manure and 86 lbs. nitrogen as nitrate	3031	1908	4052	47·1
MANGEL WURZEL, 8 YEARS, 1876-1883.				
Mineral manure	759	...	...	...
Mineral manure and 86 lbs. nitrogen as ammonia	1889	1130	2376	27·6
Mineral manure and 86 lbs. nitrogen as nitrate	2129	1370	2771	32·2
POTATOES, 10 YEARS, 1876-1885.				
Mineral manure	1021	...	...	...
Mineral manure and 86 lbs. nitrogen as ammonia	1783	762	1507	17·5
Mineral manure and 86 lbs. nitrogen as nitrate	1752	731	1416	16·5
BEANS, 8 YEARS, 1862 AND 1864-1870.				
Mineral manure	726	...	...	...
Mineral manure and 86 lbs. nitrogen as nitrate	992	266	474	5·5

Nitrogenous manures give their best results when applied to gramineous crops, that is, to the cereals and grasses, and to mangels. For the other root crops nitrogen is not so *important, while for the leguminous crops it gives* very little increase. This last fact is due to the exceptional powers of the leguminous crops for obtaining the nitrogen they need. The following table summarises the increase of different crops obtained by the addition of nitrogenous manures:—

TABLE XL.

Increase of Various Crops by addition of Nitrogenous Manures.

	Produce per Acre.		Increase from addition of Nitrogen, per cent.
	Mixed Mineral Manure.	Mineral Manure with Ammonia Salts.	
	Bushels.	Bushels.	
Wheat	15	33⅛	120·8
Barley	22¾	43½	94·4
Oats	24½	59	140·8
	Tons. Cwts.	Tons. Cwts.	
Mangels	5 14	16 1	181·6
Swedes	2 16	4 12	64·3
Potatoes	3 9⅞	6 4¾	78·4
	lbs.	lbs.	
Beans (corn)	1162	1356	16·7
Red clover (hay)	4171	4555	9·2

In the above table the figures relating to beans and clover are the average results of various applications of mineral manures and of mineral manures with nitrogen respectively.

The nitrogenous manures are best classified according to the state of combination in which the nitrogen exists in them. They have already been classified on page 105 into four divisions: (1) nitrates, (2) ammonium salts, (3) animal

remains, and (4) nitrogenous guanos; and this is really a classification according to the availability of the nitrogen for the plant's use. In the case of the nitrates the nitrogen is actually in a condition in which the plant can take it up at once without change. In the ammonium compounds the plant cannot make direct use of the nitrogen, but the latter is readily converted into the form of nitrate in the soil and so becomes valuable. In the third group the nitrogen exists in the form of organic compounds and the decomposition of these is comparatively slow, so that generally the nitrogen is prepared for the use of the plant rather slowly. In the fourth class, the guanos, the nitrogen holds an intermediate position with regard to its rapidity of action, part becoming available very rapidly, while much of it exists in compounds which decompose only slowly.

The Nitrates.—As just stated, these are the most rapid in action of the nitrogenous manures, and consequently they should only be applied to the soil when the plant is actually ready to make use of them, otherwise there will probably be a considerable waste, for nitrates of all kinds, it will be remembered, are easily washed out of the soil by rain. Nitrates are therefore supplied in the spring as top-dressings to crops actually established in the soil, and until spring growth has commenced in the crops it is inadvisable to use nitrates. The nitrates are also particularly suitable for dry seasons, owing to their great solubility and the fact that no change need take place in them before the plant can use them.

Nitrate of soda is obtained from Chili, and is sometimes called cubic nitre or Chili saltpetre. It can usually be obtained of 95 per cent purity, that is, with 95 per cent of actual nitrate of soda, the remaining 5 per cent consisting chiefly of common salt, water, and usually a little sand. Having this composition, nitrate of soda contains about 15 per cent of nitrogen.

Owing to this large quantity of nitrogen and the consequent stimulating effect of the manure on the plant, a better result is generally obtained by applying it in two small dressings rather than in one larger dressing, thus spreading the supply of nitrogen over a longer period, and so exposing the nitrate to less chance of loss by drainage. It is important,

however, that it should not be applied too late in the plant's growth, for all plants take up the greater part of their nitrogen during their early stages of growth. Nitrate of soda is hygroscopic, and therefore, when applied to the soil, it takes up moisture from the surrounding soil or the air, even though the weather be dry. In this way it gradually dissolves and diffuses through the soil, so that it soon reaches the roots of the plant, though applied as a top dressing. Of course in time of rain it is washed down rapidly into the soil.

Nitrate of potash is perhaps slightly better for plant growth than nitrate of soda, owing to the fact that it supplies both nitrogen and potash. Its action is similar to that of nitrate of soda. It is not very much used as a manure, owing to its high price considered with regard to the amount of nitrogen it contains. The quantity of nitrogen in commercial samples is usually 12 to 13 per cent.

Salts of Ammonium.—The only ammonium compound important as manure is sulphate of ammonia, which is obtained from gas-works as a by-product in the manufacture of coal-gas. It may easily be obtained of from 97 to 99 per cent purity, and then it contains about 20 to 21 per cent of nitrogen. In common with other ammonium compounds, it is not so rapid in its action as the nitrates, for before it can be taken up by the plant it is necessary for the ammonia to be acted upon by the nitrifying organisms, and for the nitrogen to take the form of nitric acid. Sulphate of ammonia may therefore be applied a little time before the crop actually requires it, in order to give time for the action of the nitrifying organisms, and as most soils have considerable powers of absorbing compounds of ammonia, there is little risk of loss of nitrogen in the interval by drainage. It is not until the ammonia has been converted into nitric acid that it is likely to be washed away. The nitrogen in sulphate of ammonia is generally rather cheaper than the nitrogen in nitrate of soda, though the cost per ton of the former manure is greater than that of the latter, but it is not quite so active and does not give such good results on most crops. The following is a summary of the produce of various crops grown at Rothamsted, with equal quantities of nitrogen in the form of nitrate of soda and ammonium salts:—

TABLE XLI.

Average Produce of Various Crops manured with Nitrate of Soda and Ammonium Salts respectively.

	MIXED MINERAL MANURE.	
	With Nitrate of Soda.	With Ammonium Salts.
Wheat (40 years) . . .	35⅜ bushels	21¼ bushels
Barley (40 years) . . .	45½ ,,	43½ ,,
Oats (5 years) . . .	57½ ,,	59 ,,
Meadow hay (20 years) . .	57 cwts.	51 cwts.
Mangels (15 years) . .	18 tons 10 cwts.	15 tons 9⅝ cwts.
Potatoes (15 years) . .	6 ,, 4⅝ ,,	6 ,, 4⅜ ,,

Thus in every case the returns are considerably in favour of nitrate of soda as compared with ammonium salts, except with oats, in which case, however, it must be noticed that the experiments only extended over a short series of years, and are therefore not so decisive as those of other crops. In the case of potatoes the two sources of nitrogen are apparently of equal value to the plant.

Ammonium chloride or sal ammoniac contains a very large proportion of nitrogen, generally from 24 to 25 per cent, but in spite of this it is not so effective a manure as sulphate of ammonia, apparently because the chlorine it contains is more harmful to the plant than the sulphuric acid of the sulphate. It probably acts to some extent by assisting in the solution of plant food in the soil, as well as by supplying nitrogen to the plant.

Gas liquor, another by-product from gas-works, is of value because it contains compounds of ammonium, but it varies very much in composition, sometimes containing large quantities of valuable material, sometimes only very little. In any case it should be diluted before it is applied to the land, the usual dilution being 1 part of gas-liquor to 5 or 6 of water. As a manure it is perhaps chiefly employed on

grass land, where it is said to be efficacious in killing moss, and it is also employed in its fresh undiluted state for killing insect pests, though for that purpose it must be used when the land is free from crop. When used as a manure it is better applied in rather moist weather, otherwise it is liable to burn the crop, and so do temporary harm.

Soot is valuable as manure only because of the nitrogen it contains, which exists in quantities varying from 2 to 4 per cent, chiefly in the form of compounds of ammonium. It is used principally for application in the spring to crops sown in the previous autumn, especially wheat. Its effect is probably partly due to its influence on the temperature of the soil, its dark colour causing a greater absorption of heat. It is also used to protect crops from the attacks of insects, the dusty, bitter character of the soot protecting the leaf from such insects as the turnip fly, etc. It also assists the crops against such attacks, because the nitrogen of the manure promotes a greater growth of leaf to take the place of those destroyed by the insect.

Animal Substances containing Nitrogen.—These are not of much importance as manure. One of the most useful, perhaps, is dried blood, which is, however, only used to a small extent. In its commercial form it contains about 8 or 9 per cent of nitrogen or often less, owing to the admixture with the blood of a good deal of earth or other material used for absorbent purposes. Although the proportion of nitrogen is considerable, yet it is in the form of organic compounds that break up rather slowly, so that the manure is some time in producing its effect. In the case of corn it is found to give its best effect if applied in the autumn.

Horn, hides, hair, feathers, etc., are all very similar in their composition. When free from impurity they contain as much as 14 or 15 per cent of nitrogen, but this is in such a state of combination as to be excessively slow in its action. Its value, therefore, is very low, and, generally speaking, the use of such manures cannot be recommended. These substances are used to some extent for making compound manures, and particularly if treated with acid the nitrogen becomes more active. It is also quickened in its action if the manure be made into a compost.

Waste Wool and Shoddy.—The nitrogen of these sub-

stances is present to the extent of about 7 per cent or less, and in its character and rapidity of action is similar to that of the preceding substances. If the grease is extracted from the wool, the nitrogen is rather more active than it otherwise would be, because the presence of oil protects the wool from decomposition. Wool refuse and shoddy are sometimes treated with acid, which has the effect of making them decompose more quickly. They are chiefly used for manuring hops.

Nitrogenous Guanos.—The guanos consist of the excrement of sea birds, deposits of which are found to an enormous extent about the coasts and islands of South America and other countries. The composition and value of the deposits vary very much, according to their age and the climate in which the accumulation has taken place. The greater part of the nitrogen readily becomes soluble, and if a deposit of guano has been exposed for a long time to the weather, much of the nitrogen will have been washed away, and the residue will be chiefly insoluble, and consist to a considerable extent of phosphate of lime. The influence of climate is felt in the same way; if it be wet a large proportion of the nitrogen will be lost, but if it be dry the guano will be comparatively rich in that substance.

Peruvian guano is perhaps the most important of the nitrogenous manures, the accumulation having to a great extent taken place in almost rainless districts, so that in spite of the age of the guano it is usually fairly rich in nitrogen. The best deposits, however, have been worked out, and in consequence the composition of the present Peruvian guano is inferior to that of twenty years ago. Average samples of Peruvian guano contain 5 to 8 per cent of nitrogen, and from 20 to 35 per cent of phosphate of lime. But very wide variation takes place, owing to the quantity of material present, such as sand, which may exist to the extent of less than 10 per cent or more than 30 per cent. In the same way the proportion of water ranges from less than 8 per cent to upwards of 15 per cent. This difference in the composition of guano not only applies to samples obtained from different sources, but even to those from different parts of the same cargo. For example, Voelcker quotes an instance of samples taken from the same cargo of guano which contained

7·87 per cent and 10·32 per cent of nitrogen respectively, and 26·99 per cent and 30·12 per cent of total phosphate.

Peruvian guano should be in a dry, finely-divided state, *and if squeezed in the hand should not cling together in a* sticky mass. It should be of moderate weight, about 70 to 80 lbs. a bushel being the usual limit; if heavier than this, the proportion of sand or moisture is greater than it should be. The colour should be rather light, and the smell should not be very pungent, for if so a loss of ammonia is taking place.

Ichaboe guano consists of the fæces of sea birds collected when quite fresh. The deposit formed during each breeding season is collected immediately afterwards, when the birds have migrated, and is at once stored in pits for protection from the weather. There is thus little risk of loss of nitrogen, and little time for any fermentation to take place, and consequently the percentage of nitrogen is usually high, fairly good samples containing 10 or sometimes 11 per cent. The amount of phosphoric acid is equal to about 20 to 25 per cent of phosphate of lime. Its recent origin is shown by the presence in it of quantities of feathers and other animal remains, which partly make up the amount of the nitrogen in the manure.

CHAPTER XVI

PHOSPHATIC, POTASSIC AND OTHER SPECIAL MANURES

PHOSPHATIC guanos, like the other phosphatic manures obtained from natural sources, are chiefly valuable for the tricalcic phosphate, or tribasic phosphate of lime which they contain. This is an insoluble substance, which, however, slowly becomes available as plant food. It has already been explained that guanos are found varying in composition from the most highly nitrogenous to those containing very small proportions of that element, and that, generally speaking, those poor in nitrogen are rich in phosphoric acid. Accordingly, phosphatic guanos are usually obtained from old deposits which have been found in rainy districts, chiefly from various islands in the Pacific. The material left after a long exposure to the weather is chiefly mineral matter, containing phosphate of lime and of magnesia, together with various impurities, sand, oxide of iron, etc. Voelcker gives the following list of phosphatic guanos, and the average percentages of the various constituents shown in the table are largely compiled from analyses by that chemist:—

TABLE XLII.

Percentage Composition of Phosphatic Guanos.

Variety.	Organic Matter.	Nitrogen.	Phosphoric Acid = Tribasic Phosphate of Lime.
1. Mejillones guano . . .	7	0·85	70
2. Falkland Island guano . .	24	4·35	27
3. Patagonian guano . .	11	1·25	23
4. Patos Island guano . .	10	0·95	50
5. Gulf of California guano .	11	0·80	80
6. Raza Island guano . .	...	...	83
7. Curaçoa guano . . .	7	...	70
8. Quito Serrano Island guano .	...	...	70
9. Petrel Island guano . .	...	...	66
10. Coral Island guano . .	11	0·40	77
11. Booby Island guano . .	10	...	50
12. M'Keen Island guano . .	9	0·25	50
13. Baker Island guano . .	7	0·40	75
14. Howland Island guano . .	6	...	75
15. Jarvis Island guano . .	10	...	50
16. Birds' Island guano . .	5	...	80
17. Shaw's Island guano . .	...	...	75
18. Flint Island guano . .	...	...	80
19. Malden Island guano . .	5	...	73
20. Enderbury guano . . .	9	0·40	62
21. Sarbuck Island guano . .	7	0·40	73
22. Lacepede guano . . .	...	..	75

It should be explained that for convenience it is usually assumed that the whole of the phosphoric acid present exists in the form of tribasic phosphate of lime ($Ca_3P_2O_8$), and the percentage of this latter substance is usually stated in the results of analyses.

Many of the varieties of guano mentioned above vary very much in their composition, and indeed the surface layers of any deposit are usually more highly phosphatic than the lower layers, owing to their greater exposure to the weather. Most of the phosphatic guanos are used more for the manufacture of superphosphate and for various compound manures than for direct application to the soil.

Mineral Phosphates.—The chief mineral phosphates which are used for fertilising purposes are—

The Coprolites, which are phosphatic nodules, in some cases being the fossilised excrements of animals, probably reptiles, in others being small phosphatic concretions of purely mineral origin.

Rock-forming Minerals, particularly apatite and phosphorite.

The "Rock-Guanos," which have apparently been formed beneath deposits of guano by the rain washing down alkaline phosphates into the porous rock, where they have combined with the lime of the rock, forming phosphate of lime.

Impure Phosphates of Alumina, such as the Redonda phosphate. The following are the chief varieties of mineral phosphates used in this country:—

TABLE XLIII.

Amount of Phosphoric Acid in Various Mineral Phosphates.

Minerals.	Phosphoric Acid × Tribasic Phosphate of Lime per cent.
Coprolites, Cambridge	60
do. Suffolk	55 to 60
do. Bedford	50
do. French	40 to 50
do. Russian	45 to 50
Phosphorite, Bordeaux phosphate	65 to 70
do. Spanish or Estramadura phosphate	60 to 70
Apatite, Canadian phosphate	70 to 80
do. Norwegian phosphate	70 to 75
South Carolina phosphate (land)	50 to 55
do. do. (river)	55 to 60
Florida phosphate	55 to 75
Algerian phosphate	60 to 65
Rock Guano, St. Martin's phosphate	60 to 70
do. Aruba phosphate	65 to 70
do. Navassa phosphate	65 to 70
do. Sombrero phosphate	70 to 75
do. Columbian guano	80 to 85
Alta Vela phosphate	45 to 55
Redonda phosphate	70 to 80

Most of these materials are used for the manufacture of superphosphate, for which purpose they require to be finely crushed before manufacture.

Alta Vela and Redonda phosphates are not, however, of much use for manurial purposes, because phosphate of alumina does not form a marketable superphosphate. They have, however, been used to some extent for the purification of sewage. If very finely ground, many of the mineral phosphates may be applied direct to the soil as a manure, and will give fairly good results, but their use in this way depends entirely upon the fineness of grinding, which makes them much quicker in their action, and therefore more valuable.

Bone Phosphates.—Bones, in some form or other, formed almost the first artificial manure used to any considerable extent in this country. Formerly they were used coarsely ground or crushed in the form of inch bones, or sometimes half-inch bones, but gradually it has become the custom to use them more finely ground, quarter-inch bones, bone-meal, and bone-dust being now the most common forms of application to the soil. The more finely the bones are ground the greater their cost, but they are so much more rapid in their action when finely ground, owing to the larger surface exposed to the action of the weather, that the extra expense is well repaid. Many farmers, however, prefer to apply rather coarsely-ground bones, saying that they last longer, that is, that a larger residue is left in the soil after the first crop is removed. This is of course true, and it becomes a question whether it is better to invest in a manure the action of which is spread over a number of years, or in one which will give its return in one or two seasons. From a commercial point of view there is no doubt that the latter plan is the better one, and it must also be remembered that its application and use are better under control when the manure is in a form which acts more rapidly, so that the plant food contained in it can be directly applied to the crop that requires it most. An example of the different effect of coarsely or finely-ground bones is given in the *Journal of the Royal Agricultural Society* by Hannam, who found that an experimental plot dressed with finely-crushed bones produced a crop of about $10\frac{3}{4}$ tons of turnips, while

the same amount of coarsely-ground bones applied to another plot of the same area returned only about 7¾ tons. The ordinary commercial bone-meal contains about 50 per cent of phosphate of lime, and about 3½ per cent of nitrogen. The nitrogen is contained in the organic constituents, and consequently, anything which reduces the amount of organic matter also reduces the percentage of nitrogen. For instance, in steamed or boiled bones, from which part of the organic matter is removed by steaming or boiling, the amount of nitrogen is usually only about 2 per cent; but of course the proportion of phosphate of lime is higher than in raw bones, and generally averages about 60 per cent.

Bone Black or Animal Charcoal in its freshly manufactured state is too expensive for use as a manure. It is chiefly employed in sugar refineries for decolourising the crude sugar. After a time it loses its efficacy for this purpose, but is again rendered useful by heating. It may thus be revived several times before finally losing its value as a decolourising agent. In time, however, much of the organic matter it contains is burnt away, and little but mineral matter is left. In this form it is used by the manure manufacturer, for it contains from 60 to 75 per cent of phosphate of lime.

Bone Ash—that is, as its name implies, the ash obtained by calcining bones—was at one time used to a great extent as phosphatic manure, and was imported in enormous quantities from South America. The supply, however, has fallen off to some extent of late years, and other forms of phosphates have taken its place. It is a highly phosphatic manure, containing about 75 per cent of phosphate of lime, and this is in a rather active form.

Precipitated Phosphate is obtained from glue factories, and consists of the phosphates of bones which have been dissolved to allow of the extraction of glue, and precipitated by chemical means. It is also obtained from basic slag (see p. 153). It is in a very fine state of division, and is a more active form of phosphate of lime than most of the preceding.

Superphosphates.—Superphosphates are produced by the action of an acid upon the ordinary raw phosphates of commerce. They may be divided into three groups, according

to the origin of the material used in their manufacture, namely:

Mineral superphosphates.
Bone superphosphates, or dissolved bones, and
Dissolved guanos.

The action of the acid upon the phosphate is that the tricalcic phosphate is converted into a monocalcic phosphate, that is, into a soluble condition. The following chemical equation shows the action which takes place:—

$Ca_3P_2O_8$	+	$2H_2SO_4$	=	$CaH_4P_2O_8$	+	$2CaSO_4$
Tribasic or Tricalcic Phosphate.		Sulphuric Acid.		Monobasic or Monocalcic Phosphate.		Sulphate of Lime.

The theoretical action, as shown in the above equation, does not take place completely on a manufacturing scale, and at the end of the process there is always some insoluble phosphate which has not been acted upon by the acid, and some acid which has not combined with the phosphate of lime. The larger the percentage of tricalcic phosphate in the original material, and the more finely it has been ground, the larger will be the proportion of the tricalcic phosphate converted into monocalcic phosphate. The quality of the original phosphate also affects its value for manufacturing purposes very considerably. The most common impurities are carbonate of lime, oxide of iron, and alumina. If any of these exist in the phosphate they will combine with part of the acid added, so that a larger quantity of acid will be required to convert the phosphate into superphosphate than if these impurities were absent, while the resulting superphosphate will be less concentrated in character, and contain more sulphate of lime, iron, or alumina, as the case may be. If perfectly pure materials were used, and the action took place to the fullest extent, there would be a little more than 46 per cent of monocalcic phosphate present in the superphosphate produced, but no such proportion ever occurs in commercial superphosphate, owing to the two causes mentioned, viz. the presence of impurities and the incomplete character of the chemical action. The following shows the composition of certain samples of superphosphates obtained from various sources:—

TABLE XLIV.

Composition of Superphosphates.

	Source.				
	Mineral (Dyer).	Bone-Ash (Voelcker).	Mineral (Voelcker).	Bones (Voelcker).	Guano (Cameron)
Moisture	16·03	5·65	18·69	11·85	17·06
*Organic matter . / Water of combination .	10·18	3·51	9·32	28·90	51·50
Monobasic phosphate of lime	20·56	23·13	11·53	15·46	17·10
Equal to tribasic phosphate of lime made soluble	(27·24)	(30·65)	(19·25)	(20·48)	(22·65)
Insoluble phosphates . .	5·39	0·86	10·50	18·08	3·40
Sulphate of lime, etc. . .	45·82	66·79	43·89	24·27	12·42
Silicious matter . . .	5·19	3·55	5·40	3·85	1·10
	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen .	...	...	...	1·93	...

It should be noticed that in ordinary trade phraseology the term "soluble phosphate" does not mean the percentage of monocalcic phosphate present, but the amount of tricalcic phosphate which has been acted upon by acid to produce the monocalcic phosphate. For example, in the above table, the superphosphate manufactured from bone ash would be described as containing 30·65 per cent soluble phosphate, though it will be seen that it contains only 23·13 per cent of monocalcic phosphate.

The sulphate of lime always present in superphosphate, and the insoluble phosphate, serve one useful purpose in improving the consistency or condition of the manure, rendering it drier and more easily distributed. Without it the superphosphate would have a pasty, moist consistency, and be very unsuitable to apply to the land.

When superphosphate is kept for any length of time the monocalcic phosphate it contains tends to "revert" or "retrograde," that is, to become less soluble. This takes

place to a great extent by a combination of the monocalcic phosphate with some of the tricalcic phosphate present, forming a bicalcic phosphate intermediate in its composition and solubility between the monocalcic and the tricalcic phosphates. The monocalcic phosphate also combines with the oxide of iron present, forming an insoluble phosphate of iron.

The monocalcic phosphate, though soluble in water, is not taken up by the plant direct, for, as soon as it is supplied to the soil and is washed into it by rain, it combines with the *lime of the soil and forms tricalcic phosphate*, that is, assumes once more the state of combination in which it originally existed. The chief advantage, then, of using soluble phosphates is that a much more even distribution through the whole of the surface soil is obtained by the rain carrying down the phosphate in solution than is possible in any other way, and when this soluble material again becomes insoluble it is in a much more finely-divided state than could be *obtained by any mechanical means*. Consequently, in that state it is more easily dissolved than in its original condition, for it must be remembered that though tricalcic phosphate is usually termed "insoluble phosphate" it is to a slight extent soluble in water. The extent of the advantage gained by using dissolved phosphates has been shown by almost innumerable experiments, so that it will be enough to quote the result of one carried out at Woburn, where 6½ *cwts. of ground coprolites gave a produce of* 21 tons 2½ cwts. of swedes per acre, while 5 cwts. of dissolved coprolites gave about 24 tons 5¾ cwts. In the same way, with bones, 3½ cwts. of dissolved bones yielded 23 tons 5¾ cwts. of swedes, while 3 cwts. of bone-meal produced 19 tons 5½ cwts. In every case the cost of the manure was about the same, namely, 22s. 6d. to 22s. 9d. per acre.

It will be noticed that the action of superphosphate in the soil requires the presence of a certain quantity of lime to reconvert the soluble phosphate into an insoluble state, and it has been found that in soils deficient in lime, undissolved phosphates will often give as good results as, or better than, those which have been treated with acid. This may be partly due to the presence of free acid in the superphosphate, which is of course harmful to plant life.

Basic Slag, Basic Cinder or Thomas Phosphate.—This is a

slag obtained as a by-product in the Thomas-Gilchrist process of converting iron into steel, the object of the process being to extract from the iron as much of the phosphorus it contains as possible. The composition of the slag is given by Professor Kinch as follows[1] :—

	Per cent.		Per cent.
Phosphoric acid	16·5	Sulphuric acid	·2
Lime	49·0	Silica	7·0
Magnesia	5·0	Alumina	2·0
Ferrous oxide	11·0	Moisture, carbonic acid, alkalies, etc.	1·5
Ferric oxide	3·5		
Manganese oxide	3·5		
Vanadium oxide	·2		100·0
Sulphide of lime	·6		

The amount of phosphoric acid given above is equivalent to about 36 per cent of tricalcic phosphate of lime, but apparently it is not present in that form, being combined with a larger proportion of lime in the form of tetracalcic phosphate, that is, one containing four parts of lime instead of three as in the tricalcic phosphate. This tetracalcic phosphate is more soluble than the tricalcic phosphate, and consequently is more active. In five parallel experiments carried out in different parts of the country, under the direction of the above-named chemist, the following results were obtained :—

TABLE XLV.

Weight per acre of Swedes grown with Thomas Basic Cinder and with Superphosphates.

No. of Expt.	No Manure.		Thomas Basic Cinder, 4 cwts.		Superphosphate, 3 cwts.	
	Tons.	cwts.	Tons.	cwts.	Tons.	cwts.
1.	11	18¾	15	16½	15	7½
2.	6	9½	11	16¾	15	11
3.	13	6	14	8¼	14	3⅜
4.	8	8⅜	11	17⅛	13	6¼
5.	11	8⅛	12	6¼	13	4⅝
Average	10	6¼	13	5	14	6½

[1] *Journal R.A.S.E.*, 3rd series, vol. i., p. 130.

It is generally considered that 5 cwts. of slag are equivalent in effect to about 3 cwts. of superphosphate, but this depends to a great extent on the fineness of the slag. It should be obtained so finely ground that from 70 to 90 per cent will pass through a sieve having 10,000 meshes to the square inch, and in many cases even finer grinding than this can be obtained, 75 or 80 per cent passing through a sieve having 14,400 meshes to the square inch.

Basic slag gives its best results on heavy clays and peat, or other soils containing much organic matter, possibly because on those soils the lime it contains exercises a greater effect than on others. For either arable or grass land, from 4 to 6 cwts. per acre yields as large an immediate return as heavier dressings, though the latter of course leave a larger residue in the soil for the benefit of succeeding crops. As it is comparatively slow in its action, slag should be applied to the land in the autumn, in preparation for the next year's crop.

Basic slag ought never to be mixed with manures containing ammonium compounds, for it causes free ammonia to be given off, and there is consequently a great waste of nitrogen. It must also be remembered that it has the property of setting when it becomes wet, so that it should not be mixed with any damp manure, except just before use. It may be remembered that such substances as common salt and kainite are very hygroscopic, and keep themselves moist by taking up moisture from the air. If, therefore, they are mixed with basic slag the whole mass will set into hard lumps, and will be difficult to distribute evenly on the land.

Potash Manures.—The effect of the application of potash to a crop is to produce a better maturing and ripening of the plant, and to increase the amount of carbohydrates contained in it. Potash manures, however, are not always required, for many soils contain sufficient potash for the plant's requirements, so that often no return is obtained from the application of potash, while in other cases an enormous increase results. Generally speaking, the amount of potash in the soil varies with the proportion of clay which it contains, so that heavy soils least often require potash manuring, and light sandy land gives the best return.

Kainite.—This is the most important of the potash manures, and is obtained from enormous deposits found at Stassfurt and other places in Germany. It contains an amount of sulphate of potash equal to from 12 to 14 per cent of potash. It is sometimes used after having been calcined, in which case the proportion of potash is higher.

Chloride of Potassium or Muriate of Potash may be obtained of from 75 to 80 per cent purity, but as a rule it does not give such favourable results as sulphate of potash when used as manure.

Sulphate of Potash, when purified, contains about 50 per cent of potash, but is rather expensive in its pure state, and so is not often employed. A mixture of sulphate of potash and sulphate of magnesia is sometimes obtainable, and contains from 25 to 27 per cent of potash.

Wood ashes and the ashes of plants generally contain considerable quantities of potash, varying usually from about 5 or 6 up to sometimes 20 per cent.

In all these potash manures the cost of the potash contained is greatest in the most concentrated forms. It therefore becomes a question whether, in cases where the manure has to be carried long distances, it is better to employ *a comparatively cheap bulky substance or a concentrated one* costing rather more. Where the expenses of carriage are high, the more concentrated forms will often be the most economical.

Miscellaneous Manures.—Common Salt is chiefly used in this country for mangels, and also, mixed with nitrate of soda, for application to corn crops in spring. It gives specially good results on light soils, possibly because its power of taking up moisture from the air assists in keeping such soils moist. Its use as plant food is probably only slight, and much of its value is due to the assistance it gives in the solution of plant food in the soil, in this way preparing it for the use of the crop. It is also sometimes used on fallows for the destruction of weeds or insects.

Gypsum or Sulphate of Lime is not much used in this country, though a comparatively common manure in many parts of Europe and America. It acts partly as plant food, supplying both lime and sulphuric acid, and it is also probably useful by absorbing and fixing ammonia in the

soil, and partly by assisting in the solution of plant food. It should be remembered that a good deal of sulphate of lime is ordinarily supplied to arable land in superphosphate, which contains usually from 30 to 40 per cent of this substance.

Sulphate of Soda or Salt-Cake is of some slight use for application to corn and leguminous crops, and in the Rothamsted wheat experiments, on the average of 40 years, an application of sulphate of soda with ammonium salts and superphosphate gave an average return of $30\frac{3}{4}$ bushels of corn against $25\frac{1}{8}$ bushels from the same manures without sulphate of soda.

Sulphate of Magnesia.—It is usually unnecessary to apply compounds of magnesia to the soil, as most soils contain sufficient for the plant's requirements. In the Rothamsted experiments, however, the increase obtained after using sulphate of magnesia on the wheat crop was about the same as that quoted above as having been obtained by the use of sulphate of soda.

Sulphate of Iron or Green Vitriol is seldom used, but in many cases gives good results. Griffiths states that when applied at the rate of from one-half to one cwt. per acre it gives good results with most crops, though it is apparently less valuable for cereals than for roots, grass, or leguminous crops. He also states that corn crops to which sulphate of iron is applied are less liable to mildew than those grown without that manure.

CHAPTER XVII

IMPLEMENTS AND MACHINERY

Before considering the implements of the farm in detail it is well to distinguish between the uses of the three different sources of power used for farm work. These are, man-power, horse-power, and mechanical power, that is, of steam and other engines. These differ in their uses considerably.

Man-power is absolutely necessary wherever intelligence is required, as, for instance, in the feeding and management of live-stock and for the control of the other powers. But, compared with the amount of work done, it is by far the most expensive source of power.

Horse-power is more economical, and the first cost is not very great. It is applicable to most of the heavy work of the farm, the cultivation of the soil, traction or haulage of heavy materials, as well as work at the homestead, such as preparation of food for stock, pumping, thrashing, etc.

Steam-power is also useful for work at the homestead, haulage of heavy materials, and the cultivation of the land where the enclosures are large and have fairly straight boundaries, and where the soil is of an even depth, or at all events where it is not very shallow. Steam-power is also much more economical in working than horse-power, but a much larger outlay is required in the first instance. Wind, water, gas, and oil engines are applicable for all kinds of work at the steading, and in the case of oil engines may also be used for some kinds of outdoor work, though not to any great extent. They are often more economical

in their working than even steam engines, and under many conditions are much more convenient.

Implements for Cultivating the Soil.—The purposes of all implements coming under the above heading are to break up the soil so as to allow of more perfect aeration, to clean the land by removing all weeds and uncultivated plants, and to prepare a seed bed for the various crops.

The Plough. The action of this implement is to break up and invert the soil, for which purpose it cuts the surface into furrow slices, which are turned over regularly, one upon another. This is almost always the first step in cultivating the land, and is a necessary preliminary to the use of many other farm implements. The object in view in ploughing is either to expose the soil to the air, for

FIG. 15. Parts of a Wheel Plough. 1, Body. 2, Beam. 3, Stilts. 4, Handles. 5, Share. 6, Breast. 7, Breast-stay. 8, Coulter. 9, Skim-coulter. 10, Furrow wheel. 11, Land wheel. 12, Hake. 13, Draught bar.

which purpose it is desirable that as large a surface should be exposed as possible, or to prepare it for the action of the harrows, in which case a high crest to the furrow is necessary, that is, one corner or edge of the furrow-slice must stand up sharply; or to cover manure, weeds, stubble, etc., in which case the furrow-slice is laid over rather flat or broken up, instead of being laid over in one piece.

The most common form of plough is the wheel-plough shown in Fig. 15, and the chief parts in such a plough are, the beam, which is, as it were, the backbone of the implement, terminating behind in the two stilts and handles, and in front carrying the hake or bridle, which is an arrangement, varying in different makes of ploughs, for attaching the draught, either higher or lower, or more to the right or the left, as the case may require. If a

plough tends to go too deeply into its work, the draught is attached lower down, while if it tends to come out of its work too much, the draught is attached at the top of the hake. Similarly, if the plough runs into the unploughed land too much, the draught is attached to the left-hand side of the hake, and if it comes out of the land too much the draught is attached to the right hand side. The frame or body is attached below the beam, and carries most of the working parts. It varies in its size and shape according to the depth at which the plough is constructed to work, a deep frame being required for deep work. Below the body is the sole or slade, a long flat plate on which the plough runs, and at the left-hand side of the frame, next the unploughed land, is the side-plate or side-cap, which prevents the soil from falling into the open furrow, and keeps the plough true in its course in spite of the side thrust caused by the action of the breast. The breast, or mould board, is a plate of iron or steel, twisted into such a shape as to raise the furrow-slice when cut and gradually turn it over. The shape of the mould-board and its abruptness varies in different ploughs and for different kinds of work. Generally speaking, a rather short mould-board is better on heavy land, for on such land the adhesion of the soil to the mould-board causes very great resistance to the movement of the plough, and is of course greater when a long mould-board is used. The share is the part which makes a horizontal cut underneath the furrow-slice and divides it from the lower layer of the soil. It is detachable, so that different kinds of shares can be used for different classes of work. For easy cutting land a rather short share is used, but if the land be hard or stony a long pointed share does better work. For paring work a share with a wide wing is required. In any case the share must be wide enough to cut under the whole width of the furrow-slices. The coulter makes the vertical cut, dividing the furrow-slice from the land. Here, again, it is important that it should be set to cut the whole depth of the furrow. It is attached to the beam by means of a clamp, and is fixed sloping upward and backward, the angle with the ground being least where there is much material, such as long manure or weeds on the surface of the soil which might clog the implement if the

coulter were set vertically. The land-wheel runs on the unploughed land and chiefly regulates the depth of ploughing. The furrow-wheel runs in the open furrow and assists in keeping the plough upright in its work. In very heavy, sticky soils the wheels are sometimes displaced by slides or "slades," as wheels become very much clogged with soil under such circumstances. The skim-coulter is used in ploughing leys, or wherever there is surface growth to be covered. It consists of a miniature set of working parts of a plough, which turn, as it were, a very small furrow-slice in front of the plough itself, and so assist in covering the surface very perfectly.

The Digging Plough is similar in its general construction to the common wheel-plough, but the breast is made short and abrupt, having such a curve as to break up the furrow-slice, turning it over at the same time. The soil is thus left in a very loose and pulverised condition. The digging-plough is particularly useful for spring cultivation, and for work on light land. It is not so well suited for the autumn ploughing of heavy land, as, owing to the broken nature of the furrow-slices, the soil tends to run together again. Used in the spring, it effects a considerable saving in subsequent cultivation, and it is the best kind of plough for covering manure or weeds. Compared with the work done—that is, the amount of soil moved—the draught of the digging plough is rather less than that of the ordinary type of implement.

The Swing or Scotch Plough is also very similar to the ordinary plough, but has no wheels, and is rather shorter in proportion in the beam.

Two and Three-Furrow Ploughs of various makes are also used to a considerable extent for light land, but taking into account their many advantages, it is matter for surprise that they are not more used than is the case. In the trials of ploughs carried out by the Royal Agricultural Society at Warwick in 1892, four single-furrow ploughs of the ordinary type suited for light land required on the average 7·21 foot-pounds of work per cubic foot of earth raised, while three two-furrow ploughs averaged 7·02 foot-pounds, and two three-furrow ploughs averaged 6·54 foot-pounds. The weight of the implement compared to the work done is

partly responsible for the difference in the power required, for the weight in the multiple plough does not increase in proportion to the amount of the work the implement is capable of doing.

With the common plough the soil is laid up in "lands," having open furrows between them, and the usual method of doing this is as follows:—A distance of one-quarter the width desired for the "lands" is measured off from the boundary, and two furrows are thrown together at this point, making a ridge A (Fig. 16). The plough works round this ridge until the boundary is reached, when a total width will have been ploughed equal to one-half the width of the land, namely, a quarter the width on each side of A. From the ridge A a distance equal to the width of the land is measured to B, where the same process is repeated, a width of one-quarter of the land being ploughed

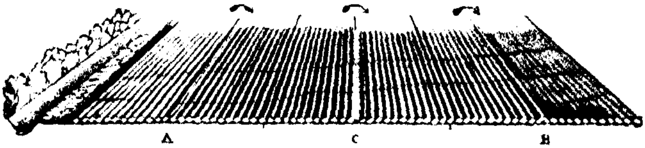

FIG. 16.—Method of Ploughing.

on each side of B. There is thus a space between the two pieces of land so ploughed equal to one-half the width of the land, and this is ploughed by turning the furrows alternately against the two ridges A and B, gradually working inwards until the work is finished in the centre by making an open furrow at C. The width of the land is again measured from B to D, when the same process is repeated. The width of the lands varies according to the soil. In very heavy soils narrow lands are best, as the open furrows allow of surface drainage, which in retentive soils is of some importance. For medium and light soils the lands may be about one chain in width. Where very narrow lands are made the ploughing is all done round the ridge first formed.

One-way Ploughs, such as turn-wrest and balance ploughs, are designed to turn all the furrow-slices over in

one direction. This is particularly useful for ploughing hilly land, for all the furrows can be laid up-hill, so as to counterbalance to some extent the tendency of the soil to work down the slope. There is also a saving of the time required in finishing the work of an ordinary plough.

Double breasted or Ridging Plough.—This consists of a beam and frame, generally like that of an ordinary plough, but attached to the latter are two rather flat breasts, one on each side, which divide and lay back the soil as the implement is drawn forward. No coulter is required, and in place of a share there is only a flattish point to steady the machine in its work. Necessarily the soil must be rather finely pulverised before the ridging plough can be used.

The Gripping Plough, which is used for making small trenches for surface drainage, and the **Draining Plough,** which makes larger surface drains, and is also used for opening up the trenches cut in deep drainage, are both constructed on the principle of an ordinary plough, but have one or more mould boards so shaped as to raise and lay over the furrow-slice at some little distance from the furrow. This is a matter of some importance, for it prevents the soil falling back into the trench and filling it up.

The Subsoil Stirrer, or subsoiler, as it is usually called, has the beam and frame of an ordinary swing or one-wheel plough; but the body is very deep, and it has no coulter, share, or mould-board, simply forcing its way through the soil and stirring it. It is used to follow the ordinary plough, and works in the bottom of the open furrow.

The Subsoil Plough is seldom if ever used, and consists of a plough adapted to take out a furrow-slice from the bottom of the open furrow left by an ordinary plough, bringing up the subsoil and mixing it with the surface layer. It is very seldom that the subsoil is of sufficient value to make this operation advisable.

Cultivators, or, as they are variously called, "scufflers," "grubbers," or "scarifiers," are used for stirring and breaking up the soil, usually after it has been previously ploughed In the case of light land, however, the cultivator is sometimes used as the first implement in obtaining a seed-bed. There are two chief kinds of cultivators, in one of which

the tines or stirrers are fastened rigidly to the frame, so that in order to lift them the whole frame must be raised. This may be done by means of a lever, or in some cases, as in the self-lifting cultivators, by an ingenious contrivance for utilising the power of the horses. Another type of cultivator has the frame attached rigidly to the wheels, while the tines may be raised or lowered by means of a lever. This is perhaps preferable to the other type, and is more commonly used for the heavier class of cultivators.

Harrows and Drag-Harrows are employed to break up the surface after other implements have been used, and to give a fine surface tilth as a preparation for the seed. In other cases it is used for covering seeds, and also frequently in cleaning land. The ordinary form of harrow used is the zigzag, which is so arranged that every tine or spike of the harrow makes a separate line on the surface of the ground. The work is thus done very evenly, and no part of the surface is missed. For heavy work square harrows are often employed, and these are usually drawn rather cornerwise across the land, so as to prevent the tines tracking with one another. Wooden harrows, at one time almost universal, are now comparatively scarce; but for light work they are still employed to some extent, being lighter than the ordinary iron harrows. The heaviest class of drag-harrows are carried on wheels, and are practically light cultivators. These also are arranged in various ways, so that the lifting of the tines from the ground may be done in various ways, either by the man or by the pull of the horses.

Rollers are used to break up clods and to level the surface of the land. They are also employed sometimes to cover seeds. The ordinary smooth roller may be of wood, stone, or iron; wooden rollers being specially used for light work, such as covering seeds, while iron and stone rollers are chiefly used for levelling the surface and breaking up clods. One form of iron roller useful for the heaviest class of work is the water-ballast roller, the cylinder of which consists of a tank that can be filled with water when increase of weight is required. This is perhaps the best way of increasing the weight of a roller, for there is no increase in the diameter of the cylinder or in the pressure upon the axle

points, as is the case when the frame is weighted. If additional weight is obtained by increasing the size of the cylinder the effective power of the roller compared to its diameter is less than if the weight is obtained on the water-ballast principle. Increased pressure upon the axle points causes a waste of power by increasing the friction.

A variety of roller principally useful for breaking up surface clods is the Cambridge roller or ring roller, which consists of a number of wheels or rings fitted on one axle, but free to turn separately. The flanges of these wheels have very great effect in crushing all roughnesses on the surface of the ground. Even more powerful is the Crosskill roller or clod-crusher, which is constructed on the same principle, but with toothed rings instead of plain ones.

Horse Hoes are used to stir the soil between the rows of growing crops, and in that way to kill any weeds that may be present, and to keep the surface soil in a finely-pulverised condition, so that it suffers less from drought. The common form of horse hoe is that adapted for stirring a single row at a time. More elaborate implements are made to work several rows at once, and these are often made on the "steerage" principle, an arrangement which allows of their being guided with great exactness.

Steam Cultivation.—Most of the common operations of cultivating the soil may be carried out by means of steam-power where the character of the soil and the size of the enclosures are suitable. Ploughing, cultivating, harrowing, and rolling may all be done in this way, and often with great economy. The implements used are, of course, far larger and heavier than those employed for horse-power, and they are drawn backwards and forwards across the land by means of a wire rope, which is wound in by an engine. There are two systems of steam cultivation, the most common, perhaps, being the double-engine system, in which two engines are employed, one at each side of the field that is to be cultivated. These work alternately, winding in the wire rope fastened between them, and in that way draw the implement backwards and forwards. In the other method, the single-engine system, the rope passes round the sides of the field to two movable "anchors," as they are called, and between these the implement works

backwards and forwards just as in the previous case. The double-engine system requires a larger outlay, but is simpler and quicker in its work; the single-engine system, on the other hand, requiring the smaller outlay, has the advantage of not compressing the headlands or sides of the field so much.

Machines for sowing Seeds—Broadcast Barrows.—The *broadcast barrow* consists of a long narrow wooden trough carried on a barrow frame, in which a spindle is made to revolve by means of gearing from the travelling wheel. The spindle, which extends the whole length of the box, carries at frequent intervals brushes or small discs, which, as they revolve, force the seed in the box through small openings in its sides or bottom. The seed is thus scattered regularly on the surface, and the work may be done very quickly, owing to the great width that can be covered at a time. Generally the barrow is only used for sowing small seeds, such as clovers or grasses.

The Suffolk Corn-Drill is the type of almost all machines for sowing seeds in rows or drills. The seed in the seed-box is raised by means of a series of revolving cups, and is emptied into a hopper, from which it travels down a tube or series of funnels to the coulter. The coulter is kept lightly pressing into the soil by means of a weighted lever. In this way a regular depth of sowing is maintained, though the coulter is still free to clear itself of any obstruction which it may meet. The movement of the spindle on which the cups revolve is effected by gearing from the travelling wheels, and by altering the size of the toothed wheels various amounts of seed may be sown per acre by the machine.

The Turnip and Mangel Drill is similar in principle to the Suffolk drill, and is commonly used for sowing turnips on the flat. There are two boxes—one for seed, the other for manure—which communicate with separate tubes, down which the manure and seed are delivered to the coulter. Various methods are employed for causing an even sowing of the manure, which, if at all damp, is likely to clog in the drill and fall to the coulter unevenly.

The Water Drill is similar in principle to the turnip and mangel drill; but in place of a box for the manure there is a tank in which liquid manure is placed and this is raised

by a series of revolving cups, and emptied down a tube communicating with the coulter. This is particularly used for sowing turnips in rather dry soils or climates, when it is found that the use of liquid manure gives a better start to the plant, and consequently will often save the crop.

The Ridge Drill, adapted for sowing seeds on the ridge, is made in several ways; but in every case the coulter runs on the top of the ridge, and is either preceded or followed by a concave roller, so made as to fit closely over the surface of the ridge. The soil is thus consolidated slightly both at the top and sides of the ridge.

Harvesting and Haymaking Machinery.—The mower, used for cutting grass and other green crops, effects its purpose by means of a knife consisting of a number of teeth working rapidly backwards and forwards in the groove of a toothed bar (the cutter bar), and so cutting like a pair of scissors. This rapid movement of the knife is obtained by gearing from one or both of the two travelling wheels on which the machine is carried, and the frame is so arranged that it can be raised or lowered by means of a lever, so that the cutter-bar may follow any inequalities of the surface.

Reaping Machines are of three kinds—manual delivery, self-delivery, and self-binding. The manual delivery machines are almost exactly similar to the mowers, except that a sparred platform is attached behind the cutter-bar, so that the corn when cut falls upon it. The man controlling the machine can at pleasure lower this platform, and so allow the corn to slide off to the ground. The corn when cut is left where the horses will pass the next time the machine comes round; and this is one of the great disadvantages of the use of the manual delivery machines, for it necessitates the tying of the crop, or, at least, the removal of the corn immediately it is cut, before the machine comes round again. Self-delivery machines are similar in the way they cut the corn; but a number of revolving rakes or sails sweep the corn across a platform fastened behind the cutter-bar, and eventually throw it on to the ground at the side of the machine, so as to be out of the way of the horses when they next come round. This is a great advantage in the use of the machine, but it is partially counterbalanced by the extra power required. Self-binders cut the corn crops,

and tie them up into sheaves. They are naturally very complicated in construction, and different makes differ considerably in the way in which the knot is actually made. They are rather heavy in draught, and sometimes cause a good deal of "shedding" of corn in the process of cutting and tying. But they are economical in saving labour, and in getting the work over much more rapidly than when tying by hand is necessary.

Horse Rakes of various kinds are largely employed for collecting hay crops together, and for getting up the corn which has not been tied in the sheaves. They consist of a number of teeth, the points of which rest lightly on the surface of the soil, and which pick up and gather in loose material with which they may come in contact. Various means are employed for emptying the rake when required, either by a lever or, in some cases, by a brake arrangement, by which the pull of the horse is utilised for raising the teeth. Hay collectors or turners are also sometimes employed, and are useful for getting the hay crop together rapidly.

Haymakers or Tedders are largely used now in the place of hand labour in the process of haymaking. They are made on two main systems—the rotary and the "kicker." The rotary haymakers consist of a number of revolving rakes or forks set so as just to miss touching the ground, but sufficiently near to pick up the hay that may be spread on the surface. As they revolve rapidly they toss the hay, and spread it evenly over the surface of the ground. The direction in which the forks revolve can be regulated. If revolving in the same direction as the travelling wheels their action is rather more gentle than if in the opposite direction. In the "kickers" the forks are attached to a series of cranks, so that they simply turn the crop over without tossing it in the air. They are generally made so that the forks work between the travelling wheels, and in this way there is less danger on uneven land of their catching in the ground. But sometimes the forks are made to cover a greater width than the travelling wheels, and in this way obliterate the wheel-tracks, and so prevent the inconvenience which sometimes occurs through the wheels pressing the hay down upon the soil. To effect this, how-

ever, the forks must be put farther back than in the previous case, and consequently, in crossing hollows, they are liable to catch on the ground, sometimes causing breakages. In some machines the advantages of both types of machine are obtained by attaching forks to a loose carriage running behind the main frame. The forks thus clear inequalities in the ground, and also obliterate the tracks of the travelling wheels.

Potato Raisers.—Various implements are used for raising potatoes, the most common of which has a beam and frame like a ridging plough, but in place of the breasts it has a number of iron bars spreading obliquely backwards and upwards from the share. At the back of the slade another set of radiating bars is placed. The machine is used for ploughing the ridges in which the potatoes are growing, when it separates the tubers from the soil, and leaves them on the surface.

Many more elaborate machines have been introduced for the same purpose, in most of which there are revolving arms which break the ridges and throw the potatoes out against a screen which is placed so as to make them fall down in a line convenient for collection. These machines, however, while very useful if the soil is dry and friable, are not suitable under all conditions, and often are so rough in their action as to bruise the tubers considerably, thus diminishing their value in the market.

CHAPTER XVIII

CROPS AND CROPPING

THE farm crops usually cultivated in this country may be divided conveniently into four classes: cereals; the pulse crops, such as peas and beans; the root crops, under which head must be included such plants as the kohl rabi and the potato, as well as the true root crops; and the forage crops. They are sometimes classified by their effect upon the soil, being divided into two groups, *exhaustive* and *restorative*. The cereals are always included in the first group, most of the members of the other classes of crops comprising the second. It must be understood, however, that the terms exhaustive and restorative merely apply to the crops as they are usually treated in the practice of farming, for many of the so-called restorative crops are very exhausting if the whole of the produce be removed from the soil. For example, in the Rothamsted experiments, it has been found that root crops exhaust the land to a greater extent than corn crops if the whole produce is always removed from the soil. In the case of swedes, the unmanured crop has given, on the average of fifteen seasons, only 11 cwts. of roots; while the plot giving the best crop for the same period, namely, that manured with farmyard manure and superphosphate, has returned on the average 6 tons 7 cwts.; that is, the crop grown without manure is little more than one-twelfth of the largest crop grown with manure under the system of continuous root-cropping. On the other hand, wheat, which is usually considered an exhausting crop, produced at Rothamsted larger average crops unmanured in proportion to the maximum crops obtained in continuous wheat cultiva-

tion, the unmanured crop having returned on the average of forty years 13 bushels of corn, against 36½ bushels, the highest average of any of the plots obtained by very heavy dressings of mineral manures and ammonium salts. From this point of view, then, the wheat crop appears to be less exhausting to the soil than the swede crop, but under ordinary systems of farm management the manure produced by the consumption of the latter by stock is retained upon the land, and so the soil is not only not impoverished, but is actually enriched by the return of some of the constituents of the manures applied to the crop, and also by any extra feed that may have been given to the animals consuming the roots. In the case of the pulse crops, however, and of all other crops belonging to the natural order Leguminosae, the actual enrichment of the soil always takes place whether the crop be removed from the land or not, owing to the large accumulation of nitrogen in the stems and roots of the plants.

The fact that some crops exhaust the soil, while others enrich it, points strongly to the advisability of alternating these two classes of crops, for by that means the restorative crops can be used to supply the plant food for the growth of the exhausting crops, and still the condition of the soil may be kept up. Consequently, it is the almost universal custom to grow crops *in rotation*, that is, to grow several different kinds of crops in regular succession. This also is an advantage from other points of view. First, different kinds of crops differ in their capacity for obtaining the various elements of plant food. For instance, clover can obtain all the nitrogen it requires with the greatest ease, while the corn crops only obtain nitrogen with difficulty. Consequently, there is an economy in growing in rotation clover or other leguminous crop and corn rather than corn crops continuously, where every crop grown would require to be supplied with the same constituent—nitrogen. Further, some crops are deep-rooted and others shallow, so that by the alternation of these two classes of plants the whole depth of the soil is drawn upon equally, and made to contribute to the growth of the crops. Also, the insects attacking the different classes of crops are generally different, and so by employing judicious rotations their ravages are

very much checked, and they are prevented from multiplying to a serious extent. A rotation also allows of the land being worked with greater convenience. Some crops give great opportunity for cleaning the land, whereas others encourage the growth of weeds, besides which the labour of the farm is more conveniently spread over the whole year when a number of crops are grown than if the farm were devoted to the cultivation of one. All these are general advantages gained by the use of rotations.

The rotations followed by farmers in this country have gradually grown into their present form, and are constantly liable to slight alterations, according to changes in the conditions affecting agriculture. At one time the only way in which land was cropped was on the out-field and in-field system, part of the land being used for corn-growing until it was quite exhausted, when it was allowed to rest, that is, to lie idle for a series of years until it had recovered its fertility to some extent. A development from this system consisted in the introduction of green crops, particularly leguminous crops, into the rotation. Thus the following is quoted by Marshall, writing in 1788, as a common rotation in the Vale of Pickering in his day:—

ROTATION 1.

1st year	Wheat, barley, or bigg.
2nd year	Oats, beans, and pulse.
3rd year	Fallow.

In this rotation it will be seen that the more restorative crops, beans and peas, found a place in the rotation, and therefore such a system of cropping was not so exhausting as the one previously described. Another example of the same system of continuous corn-growing is furnished by an old rotation followed in the Wold districts:—

ROTATION 2.

1st year. Turnips.
2nd year. Oats.
3rd year. Oats.
4th year. Barley.
5th year. Grass, allowed to remain down a number of years.

With all these systems the produce of the land was

comparatively small, but very varied cropping was hardly possible until the enclosure of land became common.

Of the rotations followed at the present day, the Norfolk four-course is one of the simplest, and at the same time a good example of the general advantages of rotations. It is as follows:—

ROTATION 3.

1st year	Turnips.
2nd year	Barley.
3rd year	Clover or grass seeds.
4th year	Wheat.

It will be seen that this realises almost all the general advantages of rotations mentioned above; for instance, the two exhausting crops, barley and wheat, are separated by the restorative crops, turnips and clover. The corn crops also require chiefly nitrogen, while the turnips require phosphatic manure, and the seeds potash and lime, and so on with the other points mentioned. But the rotation has other advantages characteristic to itself. The wheat crop is harvested in the autumn, so that the whole winter and spring are available for the working and cleaning of the soil, so as to obtain the fine seed-bed essential for turnips. Where the climate and soil are suitable, this long period may also be utilised partly for the growth of catch-crops, that is, lesser ones put in between the regular crops of the rotation. The turnips are usually fed on the land by sheep, and the manure formed in this way is left at the surface of the soil, thoroughly mixed with it, and this is just what is required for barley, which is rather a shallow-rooted plant, and therefore requires the manure to be at a shallow depth also. The barley also is a spring-sown crop, and there is therefore plenty of time for the consumption of the root crop during the winter. The seeds are sown with the barley, which is the most suitable corn crop to act as a "nurse," because it is neither so tall and strong as wheat, nor so thick and close in its growth as oats, and therefore is less likely to choke the young seeds than either of those crops. Clover obtains a good deal of nitrogen from the air, much of which it leaves in the root residue, and so enriches the soil. It is, therefore, a good preparation for wheat, which particularly requires nitrogen, while the comparatively slow growth of

the wheat crop gives time for the nitrogen to become available by the decomposition of the clover roots.

The Norfolk four-course in its typical form is chiefly suited for use on dry, sandy land, in a dry climate, but a number of modifications are followed, which makes it suitable for a considerable variety of circumstances. For instance, on poor or exposed land, where the climate is not very good, oats may take the place of wheat. In districts where the soil is suitable, potatoes are sometimes taken instead of wheat, or, in some districts, instead of turnips. Similarly, peas often take the place of clover, or, if the soil be rather heavy, beans may occupy the same place in the rotation. In all these cases the same general plan is followed in the rotation, and in most of these the same advantages are gained as in the typical Norfolk rotation.

The Norfolk four-course system has the disadvantage that on most soils clover does not succeed well if grown every four years. The land then becomes what is called "clover sick," and it is found that the clovers constantly fail. The growth of peas or beans, or sometimes tares, may be partly adopted as a means of getting over this difficulty, as in this way the clover crops may be separated by a longer interval. But this is not always convenient, and it is one of the drawbacks of the rotation that clover cannot always be grown in its regular place. Similarly, on many soils the turnip crop suffers very much from "finger and toe," and there, again, if separated by a longer interval, the disease will generally be less severe.

Of the rotations extending over five years or more, most are derived more or less directly from the Norfolk four-course or one of the variations mentioned above. For instance, the Berwickshire five-course consists of the same crops as the four-course, but the seeds are allowed to remain down for two years instead of one, thus:—

ROTATION 4.

1st year	Turnips.
2nd year	Barley.
3rd year	Seeds.
4th year	Seeds.
5th year	Wheat.

In this rotation the labour bill is reduced, as two-fifths of the land is occupied by the less costly seeds crop, and it also allows of a larger number of stock being kept, as three-fifths of the land is devoted to producing food for stock. It requires, however, a rather moister climate than the Norfolk four-course, or the seeds will not last satisfactorily for two years.

In a dry climate, and on strong land, where the conditions are suitable for wheat, the following five-course system is sometimes adopted:—

ROTATION 5.

1st year	Wheat.
2nd year	Roots.
3rd year	Wheat.
4th year	Barley.
5th year	Seeds.

In this case an advantage is gained in the superior quality of barley grown after wheat. On strong land, if taken directly after roots, the barley, though yielding a heavy crop, is apt to be coarse.

On barley soils a somewhat similiar variation is adopted, namely:—

ROTATION 6.

1st year	Barley.
2nd year	Roots.
3rd year	Wheat.
4th year	Barley.
5th year	Seeds.

thus obtaining two crops of barley out of five.

Another variation in the same direction consists of—

ROTATION 7.

1st year	Wheat.
2nd year	Barley.
3rd year	Roots.
4th year	Barley.
5th year	Seeds.

the wheat in this case following the barley and obtaining the benefit of the supply of nitrogenous matter accumulated by that crop.

Over a considerable area of the country, especially in the north of England, the following five-course system is largely adopted:—

Rotation 8.

1st year	Oats.
2nd year	Wheat.
3rd year	Roots.
4th year	Barley.
5th year	Seeds.

This course is adapted to the lighter class of soils in corn growing districts.

Where potatoes are grown successfully the following rotation is adopted to some extent:—

Rotation 9.

1st year	Potatoes.
2nd year	Wheat.
3rd year	Barley.
4th year	Seeds.
5th year	Seeds.

This requires a rather moist climate, otherwise the wheat crop will not stand very well after potatoes.

In drier districts the following variation occurs:—

Rotation 10.

1st year	Potatoes.
2nd year	Barley.
3rd year	Seeds.
4th year	Seeds.
5th year	Wheat.

This is the Berwickshire five-course with potatoes in place of roots.

Another kind of variation is adopted in Devonshire, namely:—

Rotation 11.

1st year	Mangels.
2nd year	Wheat.
3rd year	Turnips.
4th year	Barley.
5th year	Seeds.

In this case two crops of roots are grown out of five,

thus producing a large amount of food for stock, but necessitating a heavy outlay in labour and manure.

A somewhat special example may be quoted from Cheshire, which is followed on land suited for the growth of early potatoes:—

ROTATION 12.

1st year	Potatoes, followed by roots.
2nd year	Potatoes, followed by seeds.
3rd, 4th, and 5th years	Seeds.

The longer rotations are derived from those already mentioned, as, for instance, in the East Lothian six-course, which consists of the Norfolk four-course, preceded by wheat and beans or potatoes, thus:—

ROTATION 13.

1st year	Wheat
2nd year	Beans or potatoes
3rd year	Wheat.
4th year	Roots.
5th year	Barley.
6th year	Seeds.

Another variation is adopted in the Midlands and in the arable districts of the north, in which oats and turnips precede the Norfolk four-course:—

ROTATION 14.

1st year	Oats.
2nd year	Turnips.
3rd year	Wheat.
4th year	Swedes.
5th year	Barley.
6th year	Clover.

The extension may also consist in leaving the seeds down for several years. Thus in the damp climate of North Wales we find the following:—

ROTATION 15.

1st year	Oats or wheat.
2nd year	Roots.
3rd year	Oats or barley.
4th, 5th, and 6th years	Seeds.

Similarly derived from No. 6 is the following:—

Rotation 16.

1st year	Oats.
2nd year	Roots, potatoes.
3rd year	Wheat.
4th year	Oats.
5th year	Seeds.
6th year	Seeds.

oats in this case taking the place of the barley in the previous one.

Then, similar to No. 11, and also followed in Devonshire, is this course:—

Rotation 17.

1st year	Mangels.
2nd year	Wheat.
3rd year	Barley.
4th year	Roots.
5th year	Oats.
6th year	Seeds.

or, derived from the same source:—

Rotation 18.

1st year	Oats.
2nd year	Roots.
3rd year	Wheat.
4th year	Roots.
5th year	Oats.
6th year	Seeds.

the barley in the third year in the first instance, and the oats in the first year of the second being the crops introduced in addition to those of rotation No. 11. In both Nos. 17 and 18 oats take the place of barley before seeds.

Another rotation followed a good deal in the Midlands consists of No. 8, with the seeds left down two years, thus:—

Rotation 19.

1st year	Oats.
2nd year	Wheat.
3rd year	Roots.
4th year	Barley.
5th year	Seeds.
6th year	Seeds.

A different kind of rotation is furnished by the following:

ROTATION 20.

1st year	Wheat.
2nd year	Beans.
3rd year	Wheat or barley.
4th year	Turnips.
5th year	Wheat.
6th year	Seeds.

In these times, however, this last has too much wheat in it for profit.

Of longer courses one or two examples will be sufficient. Following directly from the last rotation quoted (No. 20) is the following, which is adopted on clay soils in Warwickshire:—

ROTATION 21.

1st year	Wheat.
2nd year	Beans.
3rd year	Wheat.
4th year	Oats.
5th year	Turnips.
6th year	Barley.
7th year	Seeds.

Barley instead of oats is taken before seeds, and a crop of oats is placed between the wheat and turnips.

In the Fen districts a rather similar rotation is found, allowing for the introduction of rape-seed, namely:—

ROTATION 22.

1st year	Wheat.
2nd year	Beans.
3rd year	Wheat.
4th year	Rape-seed.
5th year	Oats.
6th year	Wheat.
7th year	Seeds.

These rotations are merely a few examples of the more common ones and their variations, but it is not necessary to quote further examples, as these illustrate fully the general principles that are to be borne in mind in devising a rotation of crops.

Catch-cropping.—Catch-crops are those of minor import-

ance, which are grown between the main crops of the rotation, usually for the production of food for stock. The plants selected for the purpose are necessarily those of rather rapid growth, as there is not very much opportunity for a slow-growing crop to come to perfection. The system is chiefly followed on light soils in the warmer parts of the country, where the farmer runs little risk of getting behindhand in the cultivation of the land, and where the soil is warm and therefore favourable to growth, both late in the autumn and early in the spring. On such soils, also, the growth of catch-crops through the winter is specially useful in serving to retain nitrates which otherwise would be washed through the soils by the winter rains (see *Green Manuring*, p. 131).

The point in the rotation at which catch-crops are usually grown is before the turnip crop, the late seed-time of which in the south of England allows plenty of time for the growth and consumption of the minor crop. The catch-crops most commonly employed in this country are—

Trifolium.	Cabbage.
Rye.	Rape.
Oats for feeding.	Mustard.
Vetches.	Early peas.

according to the nature of the soil and the opportunity for growing and consuming the crop. In this way a great deal of additional food for live stock may be produced, while on light land no injury is done to the condition of the soil, though on heavy land catch-cropping is usually very limited in its application, owing to the difficulty and uncertainty of obtaining a proper seed-bed for the main crops of the rotation. As examples of the way in which catch-cropping may be carried out, one or two rotations may be quoted, for instance :—

1st year. Wheat.
2nd year. Winter beans, followed by rape and turnips.
3rd year. Wheat, followed by vetches and oats mixed.
4th year. Swedes.

and in another case—

1st year. Wheat.
2nd year. Early peas, followed by rape and turnips.
3rd year. Barley, followed by rape and turnips.
4th year. Mangels.

and again—

1st year. Wheat, followed by vetches and oats mixed.
2nd year. Rape and turnips.
3rd year. Barley.
4th year. Seeds, mown.
5th year. Seeds for forage, if followed by rape and turnips.

It will be gathered from the above that such a system could only be followed where crops ripen early in the season, and where plenty of dry weather could be depended on for the cultivation of the land. For example, the growth of rape and turnips after barley, in the second rotation quoted, would not be possible except in a warm climate and soil. The principle on which catch-cropping must be carried out is to grow as many crops as possible in the course of the rotation, so long as the regular crops are not interfered with and the fertility and cleanness of the soil is maintained.

CHAPTER XIX

WHEAT

THIS is one of the important food crops of the world, but the increase of foreign competition has caused the price of the produce to fall to a level unremunerative to the British farmer, and consequently only about half as much is grown in this country as formerly. The area annually cultivated is, however, still very large. For the most part, Scotland, Ireland, and Wales are not so well suited for the growth of wheat as England, and in England the eastern and southern counties are more suitable than the rest of the country.

There are seven species of this crop cultivated for their seed, viz. :—

Triticum vulgare or common wheat.
Triticum turgidum or English or mummy wheat.
Triticum Polonicum or Polish wheat.
Triticum speltum or spelt.
Triticum durum or hard wheat.
Triticum monococcum.
Triticum dicoccum.

A great number of varieties of these species are cultivated.

The most important species is the common wheat, which is almost the only one cultivated in this country. Of the almost innumerable varieties which have been produced by selection or other means, two main groups may be considered, viz. the white wheats and the red.

The white varieties are generally more suited for growth on a good soil and in a dry, warm climate, being, as a rule, less hardy than the red kinds. The quality of the grain is better, however, being of a light colour, with a thin skin,

and yielding a large proportion of flour when used for milling purposes. The red varieties, on the other hand, are more robust in their habit of growth, and can therefore be employed under less favourable conditions than the white sorts. The amount of produce obtained is also usually greater than from the white varieties, but the grain is of a dark colour and of worse quality for the miller.

The following are a few important varieties grown in this country:—

White Wheats—Talavera.—A good variety where the conditions are favourable, the soil warm, and for growth in a good, dry climate. It can also be used for rather late sowing where its surroundings are suitable. It tillers well, but is a delicate plant, rather liable to mildew The straw is of a very white colour, fair length, and the ear is long, but rather thin-looking, owing to the distance between the spikelets. The grain is of first-rate quality and rather long in shape.

Chidham.—Chiefly grown on dry soils, and particularly in the chalk formation. Though a winter wheat, it answers well for sowing early in the spring, but it is not suited for growth in cold climates or soils. The straw is of moderate length, and the ear is short and compact, containing plump, rounded grain, remarkably white in colour and weighing heavy in the bushel.

Hardcastle.—Rather similar to Chidham, but hardier and taller in its growth, and it is remarkable for its freedom from mildew.

Hunter's White is a hardy variety, tillering well and yielding a heavy crop of good quality. The sample sometimes contains some dark-coloured grains, but it is always bought readily by millers. The straw is long and fairly stiff.

Fenton.—A very productive variety, suitable for growth on rather good wheat land, early in coming to maturity, but suffering very much from mildew if sown in the spring and being very much injured by bad weather at harvest. The straw is rather short, remarkably uneven in length, and stands up well.

White Trump.—A variety suited particularly to calcareous soils, the grain being white and plump, and the straw long but rather weak.

Victoria White yields a full, plump grain, and specially white in colour, the straw long and fairly stiff, and the ear rather long.

Challenge White.—Similar to the above, tall in its growth, with long ears, and tillering well.

Essex Rough Chaff.—A variety coming early to maturity and succeeding well if sown in the spring. The straw is short and stiff, and the ear thick-set, with velvety, very downy chaff. It produces a large yield of grain of good quality, but it is rather liable to grow or sprout if wet weather comes on at harvest-time.

Red Wheats.—**Square Head** gets its name from the compact, thick-set appearance of its ear. It grows well on deep soils or those in high condition, for it has little tendency to lodge, that is, to be beaten down by storm. It tillers very little, so that it requires thick sowing. It ripens early, but is rather liable to mildew. The straw is of a bright yellow colour, and the grain is rather lighter in colour than that of many red varieties, and is readily sold for milling purposes.

Golden Drop.—A very hardy sort, which gives a large yield of plump grain of fair quality. The straw is of medium length, stiff and strong; the ear of a reddish-brown colour and rather thin-looking.

Nursery has a short ear and short, weak straw, and does not give a very heavy yield. On heavy soils it does badly if sown late in the season. It is a good variety to follow the sheepfold.

Red Lammas.—A productive sort, having a long ear and stiff straw.

Browick Red.—A very hardy, prolific variety, specially suitable for heavy, wet land, but the grain is of a coarse quality, and the straw is long and stiff.

Spalding.—A good variety for growth on peaty soils. The straw is long and stiff, and the grain large and plump, but of rather coarse quality.

Biddle's Imperial.—Suitable for dry soils and climates, giving a fairly large yield of rather light-coloured grain of better quality than most of the red wheats. The straw is short and stiff.

White-chaffed Red.—Suitable for growth in deep, low-lying land or soils in high condition; strong and clean in

the straw. It has a short period of growth, and can therefore be sown in the spring if necessary.

New varieties of wheat are frequently produced by cross-fertilisation, and these "cross-bred" wheats, as they are called, are often of hardier character than either of the plants from which they were derived, and frequently possess altogether new characters of value.

Of the other species of wheat, the English wheat (*Triticum turgidum*) is the only one of importance. The cone wheat or Rivett's wheat is the only variety of this grown to any extent in this country, and it is chiefly cultivated on wet, cold land, where the common wheat would not thrive. It is a very hardy plant, suffering very little from mildew, with long stiff straw and large, heavy-awned heads, which hang down at harvest-time. The strong growth of this plant gives it the name of "large" wheat, in distinction from the common wheats, the different varieties of which are known as "small" wheat. The grain is of very coarse quality and is not well suited for milling purposes.

The wheat crop succeeds best on soils which contain a considerable proportion of clay, for it is essential that they should be tenacious in character and fairly retentive of moisture. In common with other crops, however, and particularly those which are sown in the autumn, the soil must be well drained, or the success of the crop is impossible.

The method adopted for obtaining a suitable seed-bed varies according to the texture of the soil, its freedom from weeds, and according to the nature of the preceding crop. In any case the land should be clean, and a firm seed-bed obtained, with only sufficient fine mould to cover the seed and allow of its germination. A stale furrow is generally considered best for wheat, so a little time is usually allowed to elapse between the working of the land and sowing.

When wheat is grown after a fallow the land will not require cleaning, and the chief point requiring attention is to make the seed-bed firm enough before sowing. This is generally effected by working the land only to a slight depth for some time previously, so as to give the soil an opportunity to consolidate, but this is not always enough, and occasionally the Cambridge roller must be employed, or, better still, the clod crusher.

After roots or potatoes have been carted from the land the soil will also need to be made firmer. Where roots have been fed off, the trampling of the sheep will have consolidated the soil sufficiently, so that all the preparation required is to provide a shallow layer of mould to cover the seed. This is done by a shallow ploughing and harrowing, or sometimes by sowing the seed broadcast and turning a shallow furrow to cover it.

After seeds, if the land be clean, it is ploughed and the seed sown on the back of the furrow and covered by harrowing. Another plan is to work the land some time before sowing, so as to encourage the rotting of the clover stubble. If necessary, any weeds present may be forked out by hand before ploughing, but a thorough cleaning of the land should be avoided if possible, for in working out the weeds the clover roots are also removed, and the nitrogen they contain is lost. It sometimes happens that for a few feet from the sides of the field the land is full of couch, which has run out from the hedgerow, and it will then be advisable to plough a few furrows all round the field and clean them thoroughly before breaking up the rest of the land. The couch may be prevented from extending in this way by ploughing a furrow round the field close to the hedge at some time in the summer or autumn after the sowing of the clover seeds, as soon as the barley or other nurse plant with which they are put in is harvested. If the land has to be stirred after ploughing to clean it, the work must be begun earlier in the season, so as to allow the soil to set together again to furnish the firm seed-bed required. This will usually take place after heavy rain, except in very light land, which never becomes solid in texture in the way that heavy soils do.

When wheat follows peas or beans the land will probably require cleaning, and, as in the last case mentioned, will require time to allow it to run together again.

In all the above cases it is very important that the land should present rather a rough, cloddy appearance at the time of sowing, and not have a finely-worked surface. This is chiefly because the rather strong land on which wheat grows most successfully runs together in time of rain if it is worked to a fine state of division, and so forms a crust on the surface

which hinders the growth of the plant. The presence of clods on the surface is also useful by affording shelter to the young plants. On light soils it is of course usually impossible to get a rough surface tilth, but as they are generally warmer than strong land, and have little or no tendency to run together, the state of the surface is not a matter of so much importance.

If there is any difficulty in obtaining a sufficiently firm seed-bed, in consequence either of the previous treatment of the soil or its texture, the drill-presser or furrow-presser may be used to follow the plough and press the furrow slices together.

There are some varieties known as "spring" wheats because they may be sown in the spring instead of in the autumn. The most important variety is perhaps the April wheat, so called because it can be grown successfully even when sown as late as April. It produces a smaller crop than most of the autumn-sown varieties, in this respect resembling all the spring wheats. The straw is rather short, and the ear, which is also short, is bearded or awned.

The cultivation required for spring wheat differs somewhat from that carried out in the case of winter wheat. As the period of growth of the crop is so much shorter it is necessary that the soil should be in a comparatively fine state of tilth, so that the plant may the more easily obtain the food it requires. It must be remembered, too, that as there is less fear of the soil running together at that time of year the chief object of the rough seed-bed preferred for winter wheat is done away with.

It may be noticed in passing that when it is impossible to get in a crop of winter wheat at the proper time of year, it is almost always more profitable to substitute a crop of barley or oats rather than to sow spring wheat.

The manure actually required by the crop, and which may therefore be used with economy, varies according to the previous treatment of the soil and its condition. It is a common practice to use farmyard manure for the wheat crop, spreading it on the land before ploughing takes place Phosphatic manures, such as superphosphate or basic slag, may also be employed with advantage, as they hasten the growth of the plant. They should be put on the land before

the seed is sown. In the spring some top-dressing will be required, but this will be dealt with in connection with the spring management of the crop.

The selection of the seed is a point worthy of the most careful consideration. Besides deciding on a variety suitable for his purpose, the farmer must make sure that the seed he uses is of a good strain of that variety, for the pedigree of plants has as much influence on their value as that of animals has on theirs. Moreover, the whole of the seed sown should be of the same sort, for though a mixed crop of more than one variety, or of wheat and some other corn crop, often produces a larger yield than an unmixed one, yet there is always a risk of the different sorts ripening unequally and so increasing the difficulty of harvesting. A mixed sample of wheat, too, will not command such a good price as a true one of equal quality.

The seed should also be well matured, for a strong vigorous plant cannot be produced from an immature seed. Wheat having the appearance of being extremely thin-skinned should therefore be avoided for seed purposes, though it may be otherwise desirable. Large, plump grains will usually produce the best plants, small, mis-shapen ones the worst.

A change of seed is commonly resorted to every year or at frequent intervals, that is, the seed to be sown is obtained from another farm or district. This is found to produce stronger, healthier crops than where the same strain is grown on the same land year after year. The greatest advantage is gained where the seed is obtained from better soil and from an earlier district, provided that the hardiness of the plant is sufficient for the conditions under which it is brought.

It is usual to prepare the seed by applying some kind of dressing to it before sowing, to destroy the spores of the fungoid diseases, smut and bunt, and to protect the seed from birds. For the former purpose one of the commonest dressings is sulphate of copper, used at the rate of about one pound or rather more per quarter of seed, and dissolved in just enough water to moisten every grain. The corn is spread on a floor and sprinkled with the solution, and turned over with a shovel until the dressing is evenly distributed.

A strong brine is sometimes employed for the same purpose, and sometimes the liquid draining from the manure heaps, but neither of these is so efficacious as the sulphate of copper. Other substances are sometimes recommended, such as arsenate of soda, dilute sulphuric acid, hot water, etc., but these are not often used. The protection against birds most often adopted is Stockholm tar, mixed with hot water and sprinkled over the corn after cooling, while the heap is turned over until each seed is coated with tar. About one pint of tar is required for each quarter of grain dressed. As a result of this dressing the corn is too sticky for sowing, a difficulty which is got over by mixing it with fine ashes, lime, or, in fact, any dry and dusty material, and turning the mass over until the grains are once more dry and separate.

Many of these substances have an injurious effect upon the vitality of the seed, or at any rate make it slower in germination, so that very strong dressings of any kind should be avoided.

The time of sowing varies according to the soil and climate, and to some extent with the preceding treatment of the land. After a bare or bastard fallow it is customary to sow wheat earlier than after a crop. More important, however, is the variation due to the soil and climate. On wet, cold land the crop is sown earlier than on warm soils, for if not it will probably be unable to establish itself before the severe weather of winter begins. On the other hand, if it were sown early on warm land the crop would be liable to make too much growth before winter, and become "winter proud." Besides this, on wet or strong land it is necessary to sow the crop while the weather is favourable, or it may not be possible to get it in at all. As to climate, the same considerations hold good, for the wetter and colder it is the greater the necessity of sowing early. In fact the whole matter may be summed up thus: the less favourable the conditions are, the longer time the plant will require for its growth, and therefore the earlier the seed-time must be. Sowing will usually commence in September in the case of wet, cold land, but the greater part is done in October and the first half of November, while on the lighter soils in the southern parts of England it may go on up to

Christmas or even later. After this the spring wheats may be sown even as late as April, though preferably by March.

Wheat is sown by the drill or broadcast, in the latter case either by hand or, more rarely, by the broadcast machine. If drilled, the distance between the rows is usually about 8 to 10 inches, or rather less for the later-sown crops. Spring wheat, having less time to spread and occupy the ground, need not be sown at such wide intervals, about 6 to 8 inches between the rows being enough. Similarly, in very unfavourable situations, where there is little chance of the plants forming strong growth, the rows may be placed rather closer together than under conditions suited to the crop's needs.

The quantity of seed varies with the conditions under which the crop is grown. If they are unfavourable it is useless to expect the plants to attain to any great size, and therefore more seed is required to produce a full crop which will completely occupy the land. If the seed be sown broadcast a greater proportion will be wasted by being sown irregularly or at unsuitable depths, than if it be drilled, so that a larger quantity of seed must be sown to produce the necessary number of plants. Other things being equal, the earlier the crop is sown the smaller the amount of seed that may be used. Something must also be allowed for the skill of the farmer in obtaining a seed-bed exactly suited to the plant's needs. If from lack of either skill or opportunity the crop must be put in before a good seed-bed has been obtained, it is well to sow rather more seed than would otherwise suffice. The quantity sown on good land when the drill is used, and when the climate and soil are suitable, is about 5 pecks per acre or rather more. More commonly about 7 or 8 pecks per acre are sown, while for late-sown crops and under unfavourable conditions 3 bushels per acre or more may be sown. For spring wheat less than 2½ or 3 bushels is rarely used.

In the spring the land is generally cultivated with the harrows, Cambridge roller, and roller to break up the crust which usually forms on the surface during the winter, and so as to enable the plant to grow and "tiller." The plant is said to tiller when it sends out shoots and forms stems springing from the base of the main stem. This causes the

crop to thicken very much, and enables a single plant to produce a number of ears. It sometimes happens that a strongly-grown crop will show no tendency to tiller, but will use its whole strength in producing rapid growth of the main stem. A partial remedy is to feed down the crop lightly with sheep, not to eat it off close to the ground, but just to bite off the leading stem and so cause the development of the secondary shoots.

A top dressing of nitrogenous manure is often required in the spring, particularly after a wet, cold winter; and if the crop is backward, or has a sickly yellow appearance, some assistance of the kind should always be given. Soot is often used for the purpose, and besides being of value as manure it probably increases the warmth of the soil, owing to its colour. Nitrate of soda, at the rate of about 1 to 1½ cwts. per acre, is also used, applied either at one time, just when the plant begins active growth, or, better still, in two dressings, the first when spring growth commences, the other about a month later. With the nitrate of soda, salt is often used, at the rate of about 2 or 3 cwts. per acre, to keep within bounds the luxuriance of the growth of straw that results from the use of nitrate, and to make it easier to distribute the latter evenly. For the latter purpose sand and other materials of the same kind are often used. Other nitrogenous manures are also used instead of nitrate of soda, particularly sulphate of ammonia and rape dust.

Rather later in the spring weeding and hoeing are done. The first weeding may be done with advantage about the time of the spring cultivation, when many of the roots of such plants as docks and colts-foot can be got rid of before the plants begin to grow. But most of the weeding is left till later in the year, when growth has begun. Except in one or two districts corn crops are not horse-hoed, though it is perhaps the best means of keeping down the weeds, and most of the work of cleaning the land during the growth of the crop is done by hand, by boys or women, or sometimes by men. The whole crop may be gone over several times, until it has grown so tall as to prevent the work being done without injury to the plant.

Wheat shoots into ear usually between the beginning and middle of June, flowers about a fortnight later and

is ready for harvesting about six weeks after being in full flower.

The crop is ready for cutting when it has altogether lost its green colour, and when the grain is quite firm and does not yield any milky juice on being pressed. For the miller it is better cut before it is dead ripe, as the grain is then thinner-skinned, and there is less risk of loss by the seed shedding in the process of harvesting, or sprouting if the weather is unfavourable for getting it into stack. The variety of the wheat grown and the character of the crop must also be taken into account in judging of its fitness for cutting, for where there is a luxuriant growth of straw the grain is fed, so to speak, by the straw after the crop is cut, so that the ripening and improvement of the corn can continue for some time. With thin, weak straw, on the other hand, the maturing of the grain ceases very soon after cutting the crop.

Cutting is done either by hand or machine. In the former case either the sickle, the fagging-hook, or the scythe may be used. Cutting with the sickle or reaping-hook is the oldest system of cutting corn, though it is very little practised now. In it the standing corn is gathered into the reaper's left hand and cut off by the sickle with his right. The fagging-hook is a somewhat similar instrument, but in using it the reaper holds back the standing corn with a short-hooked stick and cuts it off by repeated cuts with the hook. This is a cheaper and quicker method of cutting than reaping with the sickle. In both cases, however, a long stubble is left, and consequently there is some waste of straw. More economical both of straw and labour is the scythe, which is used in the ordinary way, except that it has a cradle of some kind attached to it, so as to lay the cut corn evenly and gently in swathe and facilitate making it up into sheaves.

Of reaping machines, either the hand-delivery, self-delivery, or self-binding reaper may be used. The hand-delivery machines have the advantage that the size of the sheaves depends upon the man with the machine, so that if the crop is thin in any place they can still be kept of the same size as when the crop is thick. With the self-delivery reaper, on the other hand, the rakes sweep the corn off the

table of the machine at equal intervals of time, or rather of distance travelled by the machine, so that where the crop is thin the sheaves are small, and where it is heavy they are very large. The self-delivery machine, however, saves labour. The self-binders are of great value where labour is scarce, for by their use it is often possible to do the whole of the harvest work with the staff ordinarily employed on the farm. A further point is the speed with which the work may be done, often making it possible to save a crop in good condition, which, if cut in any other way, would be exposed to unfavourable weather. There is also a saving in the cost of harvesting as compared with other systems. On the other hand it must be remembered that binders are more likely to get out of order than other reaping machines, and that unless the crop is dry at the time of cutting, the sheaves will take a long time to become so, because they are tied more tightly by the machine than by hand. For the same reason there is sometimes a difficulty in getting the sheaves dry when the binder has been used for cutting a very weedy crop and the weeds have been tied up with the corn.

If a self-binder is not used a sufficient number of men or women should be employed, if possible, to tie up the corn into sheaves as fast as it is cut. It is then stooked or shocked, that is, the sheaves are put up in groups of about ten or twelve, standing on their butts and leaning against one another so as to form a double row. The object of stooking is to let the sun and wind act freely upon the crop and dry it thoroughly, and to do this most perfectly the length of the stook should have a direction about north and south, so that its sides may each have an equal chance of being acted upon by the sun. Another advantage of stooking is that when the crop is standing up in this way the least possible part of it comes into contact with the ground, and so it is kept drier than if it lay as it was cut. It is well, therefore, when stooks are blown down by the wind to put them up again as soon as possible.

As soon as the crop is thoroughly dry, so that there is no fear of its heating when put together into a mass, it may be carted and stacked. In the later and moister districts, where it is often difficult or impossible to save the crop in

really good condition, it is usually put up in rather small round stacks, because the corn will dry to some extent in such stacks and has not so great a tendency to heat; but in districts where the climate is comparatively dry, and the harvest early, large oblong stacks are often made. Under any circumstances the stacks are usually built on staddles, that is, a wooden or iron framework supported on uprights, about 18 inches to 2 feet 6 inches high. This arrangement prevents the possibility of the stack becoming damp from below, and to some extent protects it from rats and mice. In dry districts, however, it is not uncommon to build the stack on the ground, on a foundation of faggots or similar material, and straw. Great care is required to build the stack so as to protect the grain from subsequent injury from the weather. The butts only of the sheaves must be turned towards the sides, for the birds will take any corn exposed there. The sides must slope inwards from the eaves to the bottom, so as to let the water running from the eaves drop clear of the sides, and to minimise the chance of driving rain finding its way into the stack. With the latter object also each sheaf should, as far as possible, slope outwards, so that all rain may tend to run outwards, even if it should be blown against the side of the stack. To effect this the middle of the stack must be kept rather above the rest during the whole process of building, and finally the centre must be carried up as high as possible, so that even after the stack has settled there may be a good slope down to the eaves. Sometimes the stack is built round an open framework, which helps to hold up the centre when settling takes place, and which also to some extent prevents heating, by letting the air into the middle of the stack. When a large oblong stack is made it should be built in several parts, each containing about as much as will serve for one day's thrashing, by which means the necessity of opening more of the stack than is required, or of cutting down through it, is avoided.

When the crop has been harvested in very dry condition it is sometimes thrashed in the field instead of being stacked, but more commonly it is left some time in stack before thrashing. It may be noticed here that the continuous fall in the price of wheat for a number of years has

almost abolished a plan that was rather common at one time, that of keeping the corn unthrashed for several years in the hope of obtaining a better price. The practice, however, had little to recommend it, for though higher prices were sometimes obtained, the markets as often turned against the farmer, and in comparing the profits of the plan with those of selling some time during the year in which the corn was harvested, an allowance must be made for waste by rats, etc., and interest must be charged on the value of the crop.

There are three fungoid diseases of wheat which are important—smut, bunt, and rust or mildew.

Smut (*Ustilago segetum*), also called dust brand and blackhead, is the disease which shows itself by causing a blackening of the ear of the plant, and injuring the colour of the sample of grain. On closer examination it will be found that the flowers and their coverings, or glumes, are destroyed, and in their place is a mass of dark brown or black powder. This powder consists of the spores of the fungus causing the disease, and before the crop is ripe it is often shaken or washed from the plant. The spores, however, are very small, and may cling to the ripened seeds of adjacent plants, and so will be able to affect the next year's crop. It is only just at the time of the germination of the seed, however, that the fungus is able to obtain access to the plant. When the seed begins to shoot the spore of the fungus also sends out a fine thread or tube, which penetrates the soft covering of the growing plant, and so establishes itself within. By the time the leaf of the plant is formed the fungus has lost its power of penetrating the tissues of the plant. Once inside the plant, however, the disease spreads rapidly, gradually extending into all parts of the plant as it grows, but without producing any external symptoms of its presence until the ear is formed, when it develops enormously there, and produces the effect already described.

Bunt (*Telletia caries*), pepper-brand, blight or smut-balls, as it is variously called, attacks the plant in the same way as smut, that is, the spore begins to grow at the same time that the seed germinates, and finds its way at once into the young plant. It also gives no indication of its presence

until the ear has appeared and the seed is forming, when it causes the grain to swell up and become dark in colour, and to have a strong smell like that of fish. The seeds affected in this way remain on the plant till harvesting, and eventually find their way into the stacked corn, to which they give their own peculiar smell, and affect the flour made from it, both in colour and in odour. Happily, bunt is far more seldom met with than smut, for a comparatively small number of infected plants will cause the value of the whole crop to be much depreciated.

Rust or Mildew (*Puccinia graminis*).—The spores of this fungus are produced during the early summer, and are carried easily by the wind from place to place. If they alight on a blade of wheat or other corn or grass crop they germinate, each sending out a small thread which finds its way through one of the stomata, or pores of the leaf, and pushes its way into the tissues of the plant, breaking out here and there through the surface of the leaf to form masses of yellow or orange spores, called *uredo-spores*, which give the characteristic appearance of the disease known as rust, that is, orange lines or blotches on the leaf, from which a yellow powder (the spores) can be shaken. These uredo-spores may be carried by the wind from one plant to another, and so the disease is spread. As the season advances the marks on the leaves become darker in colour, and finally quite brown, when the disease is called "mildew." At this stage the fungus ceases producing uredo-spores, and forms larger, darker spores, called *teleuto-spores*, which cannot infect other wheat plants. These remain unchanged, usually till the spring, when, if they are deposited on the leaf of the barberry, they cause a thickening of the leaf, forming a cup, in which a third kind of spore, called an *aecidio-spore*, is produced, which, when brought into contact with the wheat plant, again causes rust and mildew.

In addition to the above usual method of reproduction, the rust fungus is able to produce uredo-spores all the year round when living on Yorkshire fog, foxtail, and some other grasses, and is thus independent of the presence of the barberry plant. This fact accounts for the fact of rust occurring extensively in districts where the barberry is unknown.

The disease injures the wheat crop by feeding on the

nutriment which would otherwise be used for growth and the production of seed. The plant is thus weakened, and the quality and quantity of the grain is diminished. The injury is most serious in wet seasons, and in either particularly low or high-lying situations, while under any conditions preventing the free circulation of air the fungus is also favoured. For instance, in very thick crops and in very sheltered fields the attack will usually be worst. It is also found that any forcing manure that will produce rank growth makes the crop more liable to the disease.

Insects attacking the Crop.—Only a short account of some of the chief can be attempted, and for full information on the subject reference should be made to some of the books dealing exclusively with it.

The wireworm is one of the most troublesome insect pests of the farm. It not only attacks wheat, but is injurious to almost every cultivated crop. The wireworm itself is the larva or maggot of the click beetle (*Elater lineatus*), and gets its name from the smooth, hard surface of its body. It is of a yellowish brown colour, and grows to about an inch or rather more in length. It lives for several years before changing to the chrysalis or pupa, and feeds upon the plant just below the surface of the ground. The means possible for counteracting its attacks are to consolidate the soil so as to prevent the wireworm working easily through it, either by Cambridge rolling or trampling by sheep, or to disturb the insect by deep cultivation, so as to expose it to the attacks of birds, and to the sun or frost. It is also well to remove from the soil anything which might serve as shelter, in which the insect might hibernate, such as cabbage stalks, etc., or to apply something injurious to the insect, such as caustic or fresh gas-lime, the latter being put on the land, of course, when no crop is growing. Rape or mustard cake is also useful, and often a stimulating manure is of service by strengthening the plant.

The wheat midge (*Cecydomyia tritici*) is a small brownish insect which often appears in immense numbers about the end of June in cornfields and pastures. It flies chiefly in the evening, hovering about the wheat plant and laying its eggs in the flower. The maggot produced is of a bright orange colour and lives in the floret, feeding on the soft

young grain. About harvest-time the maggot descends into the earth, and there changes to the pupa. It is thus impossible to do anything *to help a crop* when it has *once been* attacked. Deep ploughing of the stubbles of badly affected crops, and the destruction of grass and weeds about the sides of fields, to prevent the insect finding shelter there, are recommended as methods of preventing the recurrence of the attack. The effect on the crop is that a large amount of light, shrivelled grain is produced.

The Hessian fly (*Cecydomyia destructor*) is nearly related to the wheat midge. It is not of very much importance in this country, for though it is found not uncommonly in many parts of the country, its attacks are rarely severe. The larva feeds in the stem, weakening it and causing it to bend over as if broken by storm. Before harvest it changes to the pupa, when it has some resemblance to a seed of flax. These pupae are generally to be found in the cavings at the time of thrashing. For preventing the recurrence of the attack, in serious cases, the straw, chaff, and cavings should be burnt, so as to destroy the pupae.

The corn saw-fly (*Cephus pygmaeus*) is another insect which is occasionally harmful, but in most seasons is not very injurious. The perfect insect is black, with yellow markings, and appears early in the season. It lays its eggs in the stem of the plant, and the grub lives inside the stem, till the crop is almost ripe, when it descends to the level of the ground, and, still in the straw, hibernates, turns to a chrysalis, and finally to the perfect insect, when it comes out, ready to attack the young crop. The attack is recognised by the light, thin appearance of the ears on the affected plants, for the maggot takes away their strength and prevents the formation and development of the grain. The stubble of crops that have been severely attacked should be either ploughed in deeply or burned, some time in the autumn or winter, when the insect is sheltering in it.

The leather-jacket—that is, the larva of the crane fly, or daddy-long-legs (*Tipula oleracea*)—attacks practically all kinds of farm crops. The grub, which is of a grayish colour, with a tough wrinkled skin, from which it gets its name, lives in the ground, feeding at the surface during the night. This makes it difficult to apply any active remedy for its

attacks. It changes to the pupa in the soil, wriggling its way up to the surface just before the perfect insect is ready to emerge. The insect is most common on low-lying damp ground, and the eggs are laid on rough grass or other plants in such places, so that drainage and the cutting of grass, etc., at the roadsides and in the corners of fields are methods of partially preventing the attack.

The corn aphis (*Aphis cerealium*) is one of the large family of aphides, members of which do harm to many kinds of farm and garden crops. It is a plump green insect, which lives on the plant, chiefly about the ear and stem, and feeds by piercing its tissues and sucking its juices. The plant is thus weakened very much, and the corn becomes shrivelled and is of inferior quality. Early sown and forward crops do not suffer so much as later ones, as the plants become hard and woody, and consequently less susceptible to injury before the time when the aphides are most numerous. Nitrogenous manures are most useful in strengthening the plant. Cleaning hedgerows and waste land about the fields should be attended to, in order that the rough growth may be destroyed, which otherwise would serve as a shelter to the aphides during the winter.

False ergot, ear cockles or purples, is the result of the attack of a microscopic eel-worm (*Tylenchus tritici*) which is sown with the seed, and is raised in the plant as it grows. When the grain is formed the worms find their way into it, with the result that it becomes dark in colour (from which the name "purples" is obtained) and hard and hollow. This pest is not of very frequent occurrence, as the ordinary pickling of the seed is a good preventive.

The slug (*Limax agrestis*) sometimes injures wheat, in common with many other crops, particularly those that occupy the land during the winter. The injury is generally only serious in the winter and early spring, when the plant has comparatively little leaf and growth is at a minimum. Under these conditions the destruction of even a small amount of leaf by the slug may kill the plant. The attack is worst in moist seasons. A dressing of soot sown over the crop when the leaves are wet is the best remedy, being distasteful to the slug, and helping the plant to form more leaves.

Though the corn weevil (*Calandra granaria*) does not attack the growing wheat crop, it is too important to be passed over altogether without notice. It is a beetle which lives in and upon stored grain of all kinds, laying its eggs in little holes which it bores in the grains of corn. The grub eats away the interior of the grain, leaving it a mere shell, and passing on to another as soon as one is finished. In hot climates the corn weevil is very destructive, multiplying at an enormous rate, but in this country it is not often very troublesome. Small quantities of powdered naphthalene mixed with the grain is said to check the insect's ravages.

CHAPTER XX

BARLEY, OATS, AND RYE

Barley

This is a very important crop in England, though in Scotland, Ireland, and Wales it is comparatively little grown, owing to the unsuitability of the climate.

Three kinds of barley are grown, viz.:—

Hordeum distichum, or two-rowed or common barley, the ear of which bears two rows of seeds.

Hordeum vulgare, or four-rowed barley, also known as "bere," or, in some districts, as "bigg." This has four rows of seeds, extending from the base to the point of the ear.

Hordeum hexastichum, or six-rowed barley, so called because the ear carries six rows of seeds.

The first of these is by far the most important, and is always preferred where the conditions allow of its growth. The following are a few of the most important varieties of common barley grown in this country:—

Chevalier.—A fine variety for malting purposes, having a thin-skinned plump grain, which weighs heavy in the bushel. The straw is of medium length, but the plant spreads considerably in its growth, so that a thin seeding is necessary. It is somewhat delicate, and therefore requires favourable conditions of soil and climate, and is slow in its growth, so that early sowing is necessary.

Big Ben.—Very similar to "Chevalier," but rather hardier.

Golden Melon.—A strong-growing variety, long in the straw, and yielding thin-skinned bright grain, of good quality for malting purposes.

Goldthorpe.—Hardy and robust in its growth, with thin straw and close compact ear, the grain being of good quality and thin-skinned.

Beardless Barley.—A strong-growing sort, producing large crops, and standing up well against the storm. It gets its name from the fact that the awns usually fall off before harvest.

Naked Barley.—So called because the seed separates from the husk like wheat. It suffers, however, from the disadvantage that the grain shells out very much in the process of harvesting.

Of the four-rowed barleys two only need be mentioned: the common bere, which is coarse in quality, though very productive and hardy, and the Victoria bere, which is longer in the straw and longer in the ear and yields grain of rather better quality.

The six-rowed barleys are all of very coarse quality, and only suitable for growth in inferior soils and bad climates. They are often sown in the autumn, being then managed very much like wheat.

Barley is best suited for medium or rather light soils, particularly those of a calcareous nature, such as the soils of the chalk and oolite formations, and the light sandy marls of the trias. A rather dry climate, such as is found in the eastern and southern parts of England, is best suited for the production of a first-rate sample of barley, and indeed the season and climate are more important factors in the production of the best malting samples than the soil. According to the season, the best samples may be produced on sandy land, mixed soils, limestone land, or even on heavy clays. But, generally, strong land and soils rich in humus are not favourable for the growth of barley, for though they often produce heavy crops, the quality of the produce is generally coarse and the price obtained low. If means are taken to reduce the condition of the soil the quality may be improved, but this, of course, will be at the expense of the bulk of the crop.

In considering the cultivation of barley there are one or two characteristics of the plant that must be borne in mind. It has only a short period of growth, so that the soil must be in a very fine state of cultivation, and well supplied

weight per acre when the plant is just showing above the surface of the ground. There is a risk in this, however, of causing too much rankness of growth and slightly spoiling the quality of the crop and its even ripening. It is particularly important that the nitrate should be sown very evenly on the surface, and to make this easier it should be mixed with salt, sand, or sawdust to add to the bulk and to make it easier of distribution.

Where barley follows roots that have been pitted on the land it will tend to grow very strong and rank where the heaps stood, and where the roots have been dressed before being given to the sheep. This is owing to the plant food contained in the trimmings of the roots. The unevenness of the crop will spoil the quality of the barley, making it irregular in maturing, and likely to be laid by storms in the rank patches. In such cases any trimmings from the roots should be carefully thrown over the surface and distributed as evenly as possible.

During the spring and early summer the barley crop should be weeded, in the same way as wheat, otherwise it requires no further attention until harvest-time. It should be cut when it is dead ripe, that is, when the ears have bent over, and hang down stiffly from the top of the straw, and when all the grains of corn are of an even colour and the straw has completely lost its green tint. It is essential to wait for this stage of ripening, because for malting purposes the grain must be of an even stage of ripeness and wholly matured; otherwise the growth or germination of the seed in the process of malting is uneven, and unsatisfactory results are obtained. Sometimes the crop is cut rather earlier, and is allowed to ripen after cutting in the way already described in the case of wheat. This, however, does not produce a satisfactory sample of malting barley, the barley becoming what the maltster terms "steely."

The cutting of the crop may be done by any of the means mentioned in the case of wheat, though usually the binder is not employed so often for barley as for wheat. The reason for this is that barley, being cut when dead ripe, is rather likely to shed in the process of cutting, and the extra roughness of the binder thus causes a considerable loss of corn. The crop is usually [illegible]

as soon as cut, unless it be very full of clover or grass sown with it, in which case it is advisable not to tie it up until it has become partially dry. Moreover, many farmers prefer, if the weather is settled, to leave the barley untied for a time, because it is said that the colour is improved by exposure to the sunshine. On dry soils, where the straw is usually of short growth, the barley is often harvested loose, without tying at all, partly because of the small bulk of the crop, and partly because the straw on such soils is usually very brittle and causes a difficulty in tying the sheaves.

After building the stack the sides are often beaten with sticks or poles so as to knock out any grain that may be near the surface, and sheets are placed on the ground to catch the corn as it falls. The object of doing this is to remove any grain that might become discoloured by the weather, and which otherwise would be mixed with the unstained grain, and give an uneven appearance to the sample, injuring its value. In threshing it is a point of great importance not to set the machine too close, that is, not to set the concave or screen too near the drum. There is a great likelihood, in threshing barley, that the skin may be broken by the machine in removing the awn, unless special attention is paid to this point, and where this occurs the value of the sample for malting purposes is lessened, because it is found that injured grain often becomes mouldy in the process of malting, and a worse quality of malt is produced.

The process of malting consists essentially in the germination of the seed, by first of all soaking it in water or steeping, and then putting it on the malting floor, in a layer of sufficient depth to make it heat. Germination then takes place, and diastase is formed, which converts part of the starch into sugar. The temperature is then raised sufficiently to kill the seed and prevent further growth, the actual temperature employed depending upon the colour of malt that is required. The higher the temperature the darker will be the colour of the malt. The malt is subsequently dried, and the malt combs or malt dust, which consists of the shoots produced by the seed in germination, is screened out, and it forms a useful feeding stuff for stock. Malt itself, besides its use in brewing, is also employed for

feeding purposes, having a special value as a flavouring material when mixed with other and less palatable foods.

The fungoid diseases attacking barley are the same as those which affect the wheat crop, but they are not generally of much importance. Smut is the commonest, and perhaps most serious, owing to the dark colour it gives to the grain, thus depreciating its value. The seed is, however, seldom dressed to kill the spores of fungoid diseases. The insect pests, also, are similar to those of the wheat crop. One, however, is particularly important in connection with barley, namely, the gout fly or ribbon-footed corn fly (*Chlorops tæniopus*). The fly lays its eggs in or upon the sheath of the plant, and the maggot eats its way up the stem, forming a rough groove or furrow quite up to the ear, and sometimes partly up one side of the ear itself. The effect upon the plant is that the ear has not sufficient strength to force itself out of the sheath, and the swollen, distorted appearance of the plant in consequence of this gives the attack the name of gout. Early sowing is apparently a protection against the attack, while crops sown late or on damp land or in shady, sheltered situations are more likely to suffer than others. A forcing manure is of value in counteracting the attack when it has begun, but little else need be attempted.

Oats

The oat is the most important cereal crop in the northern and western portions of the country, for it has a special power of thriving in moist climates, and requires less warmth and sunshine than either wheat or barley. Indeed, where the soil is suitable, the best quality of oats may be grown in wet districts, even at a considerable elevation above the sea. The oat thrives well on almost all kinds of soil, provided the climate is suitable, but in dry climates the soil should be of a rather retentive nature, while in a wet climate a free-working porous soil gives better results. The oat does not generally thrive where the climate is very dry. Even in the south of England the crop does not yield so well, either as regards the quantity or quality, while in Southern Europe it is practically never grown except at great elevations above the sea. It is by no means particular as to the

state of the soil, and consequently oats are commonly grown as the first corn crop after breaking up grass land or clearing plantations or reclaiming peat land. There are four species of oats cultivated as corn crops to some extent, namely:

1. *Avena sativa*, the common oat,
2. *Avena orientalis*, the Tartarian oat,
3. *Avena nuda*, the naked oat,
4. *Avena strigosa*, the bristle-pointed oat,

the first two only being of any importance in this country. There are a number of other members of the genus that occur in pastures and hedgerows, but are not cultivated as corn crops.

The common oat is distinguished by having a spreading seed-head, regular in shape. The chief varieties cultivated are—

Hopetoun.—A variety chiefly cultivated on light soils, having a rather long seed, which produces meal of very good quality, while the straw is long but irregular in height.

The Potato Oat.—Rather unsuitable for heavy soils. The grain is short, plump, and remarkably white in colour, and the straw is rather short. There is a great tendency for the grain to shed at harvest-time.

Shirreff's.—A prolific variety, rather similar to Hopetoun, but with a level growth of straw.

Poland.—Both black and white varieties. A particularly early sort, so that it is useful for growth in late districts, and it is short and stiff in the straw, so that it succeeds well on soils in high condition.

Sandy.—Chiefly grown on peaty soils, owing to the stiffness of the straw. The grain is small and plump.

Canadian.—A very early, hardy variety, but little affected by frost in the early stages of its growth, producing a large crop of flaggy, soft straw, and a heavy yield of coarse grain.

Winter Dun.—A hardy variety, very slow in its growth. It is, therefore, sown in autumn, being cultivated like wheat, but it is sometimes destroyed by frost in severe winters, and will only succeed in a rather warm climate and soil. It is, therefore, only grown in the south of England. The straw is strong and the grain of a grayish colour, weighing rather heavy in the bushel.

Tartarian oats are distinguished from the common oats by the seed head being one-sided. There are two varieties commonly grown:—

Black Tartarian. A short strawed, quick-growing sort, producing a crop of rather thin, light grain.

White Tartarian. Slower in its growth than the black Tartarian, and producing more straw. It is largely grown on chalk soils in the south of England.

The cultivation of the crop is somewhat similar to that of barley, but owing to the superior vigour of the plant it does not require quite such a fine tilth. The ploughing and other cultivation is carried out according to the nature of the soil, partly in autumn, in the case of heavy land, or entirely in spring on light soils, and the seed is usually sown some time in February or March, or occasionally later. In this case, however, just as with barley, the earlier the sowing the better the produce, both as regards the quantity and quality. The actual time of sowing must vary with the district, as it is desirable not to expose the young plant to late frosts, so that in exposed districts liable to severe spring frosts the seed time should be later than in milder districts.

A change of seed from an earlier district is always desirable, and perhaps shows more marked result than in the case of either wheat or barley. Mixtures of different kinds of oats are often sown, and frequently yield larger crops than any one variety of oats, but care must be taken that the varieties sown are such as will ripen all together, otherwise great loss must ensue in harvesting.

The amount of seed sown is usually from three to four bushels per acre, but often heavier seedings than these are adopted, five and six bushels being not uncommon, and occasionally even more. The amount of seed must, of course, depend on the conditions, a greater quantity being required where the conditions are unfavourable; and the kind of oat sown must also be taken into account, as a plump, short grain packs more closely in the bushel, so that a smaller quantity may be sown than of light, thin oats.

Not uncommonly clovers and grass seeds are sown with oats, but the oat is not a very satisfactory nurse plant for seeds, as it grows very close and thick, and in that way may often check the seeds, and sometimes cause their total

failure. Particularly in the case of clover seeds it is desirable not to use oats as a nurse plant, because the same eelworm which causes the stem sickness in the clover plant is the one which causes the disease called "segging" or "sedging" in the oat crop, and there is therefore greater risk of the clover being attacked where it follows oats than where it follows barley or wheat.

Oats should be cut before they are dead ripe, practically as soon as the grain is firm, while the straw is still of a slightly green tint. The advantage of this is that less corn is lost in the process of harvesting, a thing specially likely to occur in the case of oats.

In districts where the straw is wanted for feeding purposes it is also very important that the crop should be cut early, for the feeding value of the straw is then higher than if the corn be allowed to ripen thoroughly before harvesting. It is a difficult crop to dry thoroughly, as the straw is of a soft character, and so dries only slowly, and if put into the stack while moist it sinks together very closely and heats at once. The sheaves are accordingly put up into small shocks, which are often hooded by placing another sheaf on the top of the shock to form a kind of thatch, and it is sometimes the custom to "gait" oats, that is, to set each sheaf up on its butt separately. Wind and sun are thus able to act very thoroughly on the crop, which dries quickly in consequence. In very moist districts oats are sometimes put up into "rickles," which are small round stacks a few feet in diameter, and in these there is less chance of heating, and the corn can dry to some extent without receiving any harm. From the "rickles" it is subsequently put into stacks, when all danger of heating is over.

The oat crop is occasionally grown for feeding whilst green, for making into hay, or for silage. In any case its cultivation is similar to that already described, but rather more seed is sown, as the object is to produce a thick growth as rapidly as possible. In this country it is not very important as a forage crop, but in many parts of the Continent and in the Colonies it is commonly employed, particularly for haymaking. Its feeding value is high, and stock eat it very readily.

The fungoid diseases which attack oats are the same as those attacking wheat; but they are not of very great

importance, and consequently the seed corn is rarely "pickled." Of insects, many mentioned as attacking the wheat crop also attack oats, in addition to which one or two others may be mentioned.

The disease known as "sedging" or "segging," or "tulip-root," is caused by an eel-worm (*Tylenchus devastatrix*). This eel worm lives in the stem of the oat plant, and causes the distortion and thickening of the stem, and prevents the proper development of the plant. The name "sedging" is derived from the appearance of the plant, which is thought to resemble sedges in its growth. The best way to prevent a recurrence of an attack of "sedging" is by means of deep ploughing in the autumn, by which all the eel-worms lying at the surface will be buried, and will not be able to reach the surface again. It is also important that clover should *not follow an infected oat crop, as it is also liable to be* attacked by the same pest. A dressing of potash manure is also said to be efficacious in actually counteracting the attack on the oat itself. Feeding the crop off is of no use whatever, for the eel-worm is not injured, but passes unharmed through the digestive systems of the animals consuming the crop, and is again returned to the land in the manure. It is thus often distributed widely over the farm, so that damage may result from this method of utilising an infected crop. It should also be noticed that the eel-worms are very easily carried from one field into another, as, for instance, in the soil adhering to implements or in any similar manner, and in this way the infection may be communicated to healthy crops.

The frit fly (*Oscinis frit*) is a small black fly which lays its eggs in or upon the stem of the oat plant, and the maggot produced lives in the interior of the stem, eating out the heart of the young plant. The leading shoot is thus destroyed, and withers, though the lower leaves of the plant are still fresh and green. This is the first symptom of the attack, and the treatment to be adopted must depend on the time of year at which it takes place. If noticed early in the season it is possible, by applying forcing manures, to cause the plant to send out strong side shoots from the base of the stem, which, if the weather be favourable, will have time for ripening. If,

however, the attack is late in the year, it is useless to expect a paying crop of corn, and it is better to feed off the crop by sheep or otherwise while green, and there may still be time to put in some forage crop after the oats, so as to get some further return from the land. Where the crop is allowed to ripen, the produce is generally inferior in quality, owing to the lateness of ripening. The attack is not usually very serious, but occasionally does considerable damage over large areas.

Rye

Rye (*Secale cereale*) is a corn crop of little importance in this country, but in many parts of the Continent it is very largely grown as the chief bread corn of the common people. It is a very hardy plant, being able to withstand unfavourable circumstances, and succeeds well on light sandy soils of a very poor description. In districts where the climate is unsuited for the growth of other kinds of corn, rye is most useful, as it ripens very quickly, and so can often be harvested when the other crops would not have an opportunity of coming to maturity.

There are three varieties of rye that may be mentioned, namely:—

1. **The Winter or Common Rye**, which is the most important kind, and is chiefly employed as a corn crop. It is, as its name implies, an autumn-sown plant, rather slow in its growth, but ripening early in the following season.

2. **The Giant Rye**, which is so called from its large, strong growth, producing much heavier crops of straw and a full crop of large grain. It is also useful for growth as a forage crop, its large bulk being in its favour for this purpose.

3. **The Midsummer or St. John's Day Rye**, which is also a very strong-growing variety, particularly soft in the straw, and is therefore useful as a forage crop. It differs somewhat in its seed-time from the other varieties, being sown in June or July, when from its very rapid growth it may produce one or, possibly, two cuttings of green food in the autumn, and sometimes another early in the spring, after which, if allowed to stand, it will still be able to produce a crop of corn.

As stated above, rye is chiefly grown in late districts, in

unfavourable climates, and on soils too sandy for the growth of the other corn crops. It can be grown on medium soils; but in such cases wheat, barley, or oats will usually yield a more paying crop than rye. Rye is also sometimes grown as a corn crop on reclaimed peat soils, and there does fairly well. The preparation of the soil and the general cultivation of the crop for seed is similar to that of wheat, a rather firm seed bed being preferable to a very finely-cultivated one. The seed is sown rather early in the autumn, at the rate of from 2½ to 3 bushels per acre. Frequently it will make strong growth during the autumn and early winter; but there is generally no risk of the plant being injured by frost as there is in the case of wheat, and there is no chance of the plant being injured by becoming "winter proud." In the case of very strong growth harm is sometimes done by snow, the weight of which bends down and crushes the crop; but this is exceptional. In the spring a small amount of cultivation is required, chiefly Cambridge rolling, in order to press the soil about the roots of the plant, and after that hoeing and weeding are carried out, just as in the case of other corn crops.

The plant usually flowers a fortnight or three weeks before wheat, and ripens, under favourable conditions, about six or seven weeks after this—that is, from about the middle of July onwards. The harvesting and stacking are similar to that of the other corn crops, and need not be dealt with in any detail.

Rye straw is very long and peculiarly tough in character, owing to its containing a good deal of pithy material, which makes it of little value for feeding purposes. It also makes it longer in rotting in the manure heap when used for litter; but, on the other hand, it gives it special value for such purposes as thatching, where the toughness and durability of the straw are of importance.

Of the fungoid diseases of the plant one only need be mentioned—namely, the ergot of rye (*Claviceps purpura*), which forms a thick growth in and upon the ovary of the rye plant and of many grasses. During the summer a kind of glutinous exudation appears in the floret of the plant, which apparently serves the purpose of attracting insects of various kinds, so that they carry the infection from one plant to another. Later the dense growth known as the

"spur" or "cockspur" is formed, which is really the resting-spore of the fungus—that is, the form in which it lies quiescent during the winter. In the spring the spur begins to produce spores, which again infect the rye or other plants. The fungus thus prevents the formation of seed, and, if mixed in any considerable quantity with rye, it makes it unfit for use as bread corn.

Of insect pests none need be specially mentioned, though several of the more common ones, such as wireworm, leather-jacket, etc., attack the plant frequently.

When rye is grown as a forage crop, for which purpose it is of more importance in this country than as a corn crop, it is commonly taken as a catch crop before roots, following a corn crop. It is sown after a single ploughing of the stubble, being drilled in rows five or six inches apart, at the rate of 3 or 4 bushels per acre. This close sowing and heavy seeding are, of course, intended to give a thick crop as soon as possible. If the preceding corn crop has been harvested early some cleaning of the land may be effected before the rye is sown. This is easily done by broad-sharing the stubble so as to cause any shed corn or weed seeds to germinate as rapidly as possible, and any plants beginning to grow then are killed, and cleaned from the land before the final ploughing for rye. Cleaning the land, however, must not be allowed to prevent the early sowing of the rye, which should take place at the latest some time in September, the earlier the better. Sown in this way the crop will be ready for cutting or folding in April, and for about three weeks it will yield a useful green food, particularly suited for cows in milk or ewes with lambs. It must be noted, however, that as soon as the ear appears the crop is practically useless for forage purposes, having become tough and woody by that time, so that stock will refuse it or waste a very large proportion of it. Thus only a small area can be economically grown for forage on a farm, as it is of no use except during the few weeks in the spring before it shoots into ear.

Rye is also sometimes grown as a green manure, the cultivation being similar to that described above for forage. Before ploughing in the crop is rolled, so as to get it covered more easily.

CHAPTER XXI

BEANS AND PEASE

Beans

BEANS (*Faba vulgaris*) are particularly adapted for strong land, especially if containing a good deal of lime; and on such soils they often take the place of roots, which do not usually succeed on heavy land. On lighter soils, if grown at all, beans take the place of clover or seeds. The chief varieties of beans cultivated in this country are—

The Horse Bean, a very prolific sort, producing a strong growth of straw, and suiting heavy land, and requiring a particularly firm seed-bed.

The Mazagan, which is rather similar to the horse bean, but finer in quality, and rather more of a garden variety than one for field cultivation, and consequently it requires the soil to be in a better state of cultivation and in higher condition.

The Tick Bean produces a small grain which weighs heavy in the bushel, and it yields a very large crop of grain, though short in straw. It is specially adapted to light soils.

The Winter Bean, which, as its name implies, is an autumn-sown variety, produces a rather small grain, but one which packs closely in the bushel, and therefore weighs a few pounds more per bushel than most of the other sorts. It is hardier than the other varieties, and can therefore withstand the cold of an ordinary winter, though it is sometimes killed by extreme frosts.

Beans may be grown either on the flat or on the ridge. On the flat the first operation is to spread farmyard manure, which may be of a rather poor and rough description. It

is found that a better crop is usually obtained where farm yard manure is applied in the autumn than in cases where it is applied in the spring. The manure is covered with the plough, usually in September, and if winter beans are to be sown, a seed-bed is obtained by harrowing, after which sowing takes place almost immediately. If spring beans are to be sown the active preparation of the seed bed, subsequent to the autumn ploughing, begins in January, and is carried out, if possible, by the cultivators and harrows, or even by heavy harrows alone, and it is desirable if possible to avoid ploughing in the spring.

The time of sowing the seed for winter beans varies from about the end of September to the beginning or middle of November, the spring varieties being put in from the middle of January to the middle of March. The kind of bean sown must be chosen with regard to the character of the soil and its condition. In any case beans should be sown only when the land is clean, especially in the case of winter beans, which give less opportunity for cleaning the land during growth than the spring varieties. It is also desirable, if the land is at all foul, to grow a short-strawed variety rather than a tall one, as there is thus better opportunity of cleaning the land.

The amount of seed required is usually from two to three bushels per acre, but it varies according to the kind of bean sown. Small beans of course contain more seeds per bushel, and therefore a lighter seeding will give the required number of plants. The seed is usually sown with the drill, which certainly gives the best results. Broadcasting has almost entirely died out, and dibbling, an expensive system, is rapidly falling into disuse. The seed is often drilled with too small intervals between the rows, and the best distance apart is probably from 18 to 24 inches, but in many cases only 12 inches are allowed, and in other cases as much as 30 may be found. The wider the rows the better chance is given of cleaning the land while the crop is growing. Beans are also sown at the time of ploughing, a small drill being fixed behind every second or third plough, so that the seed is covered by the furrow-slice. This system is more frequently followed in the case of winter beans than in the case of spring beans.

On the ridge the greater part of the cultivation is similar to that already described, but frequently the manure is applied in the spring, after the land has been ridged up. The seed may then be broadcasted and the ridges split with the double-breasted plough, so as to cover both manure and seed, throwing the latter into rough rows in the final ridges. Very often, instead of this plan, ridges are split before the seed is sown, thus only covering the manure, and the seed is drilled on the top of the ridge. By this system there is, however, a difficulty often in covering the seed deeply enough. After sowing the seed is generally covered by one, and sometimes two harrowings, and later on, when the plants are just showing above ground, the harrow is again used to break up the surface and keep it in a fine state. Hand-hoeing and horse-hoeing are also carried out as soon as possible, and the horse-hoe should be kept at work as long as the growth of the crop will allow. Winter beans are ready for harvest earlier in the year than spring beans, and in early districts the whole crop will be ready for cutting in August. The time for cutting is judged by the falling of the leaf, though generally in the south of England the crop is allowed to get rather riper than in the north. The earlier it is cut the more valuable the straw will be. Beans are cut with the machine or the fagging-hook, the former being the preferable method, though the work is very severe on the machine. Sometimes pulling the crop is adopted instead of cutting, the plants being pulled up by hand, and this is specially followed where the pods occur very low down on the stem. Faggots or sheaves are made by tying with straw bands, or sometimes peas or tares grown for the purpose, and the crop is allowed to remain for a long time in the field in order to become sufficiently dry. During this time it suffers less perhaps than any other crop from exposure to bad weather, and it may also be stacked rather damper than most other crops. This is owing to the woody, hard nature of the stem, which allows the free entrance of air into the stack, and allows drying to continue after stacking.

Of the insects attacking the bean crop, the bean aphis (*Aphis fabæ*), which also goes by the name of black fly,

black dolphin, or blight, in different districts, is one of the most important. It is a black aphis, which attacks the plant in the same way that the corn aphis attacks corn crops, namely, by boring into the stem and feeding on its juices. It thus weakens the plant and prevents the proper development of flower and seed. These black aphides first appear on the growing point of the plant, and, multiplying with great rapidity, very soon spread all over the whole plant if the weather be favourable to them. When the attack has just commenced, it has been recommended as a method of checking its ravages to cut the top of the plant off with a hook or any other means, and to remove the tops so cut from the field. In this way the insects are taken away from the plants, and what is left standing has an opportunity to ripen its seed. If the attack is severe it is useless to attempt to harvest the crop, and it may be fed off by sheep or other stock, for which it forms a good feeding material. Late-sown crops are more liable to suffer from the attacks of this insect than early ones, and spring beans than winter.

The bean weevil (*Sitona lineata*) is a small beetle which in all its stages of growth feeds on the bean and pea crops, sometimes destroying almost the whole of the leaf, and of course injuring the plant. It feeds on the leaf during the day, and at night apparently retires into the soil. The insect is difficult to detect, for on the slightest alarm it falls from the plant and remains perfectly still on the surface of the soil, where, owing to its brownish colour, it is difficult to see. Soot or lime or any dusty material sown over the crop when the leaves are damp will have the effect of checking the ravages of this beetle.

The humble bee (*Bombus terrestris*) does injury to the crop by biting its way through the calyx of the flower in order to reach the nectar. The pod produced is in consequence misshapen and contains very few, if any, seeds.

Pease

The pea (*Pisum sativum*) takes the place on light soils, especially if calcareous, that beans occupy on heavy land. Its usual place in the rotation is in the place

CHAPTER XXII

THE ROOT CROPS

THE root crops include some of the most important plants grown on the farm. The object of their cultivation is to produce as large a quantity of green food as possible, which may be available for use during the winter, and at the same time to clean and cultivate the soil so as to obtain to some extent the effects of a bare fallow. The most important root crop is—

The Turnip

Two species of this plant are cultivated, namely:—

1. *Brassica rapa* or common or soft turnip.
2. *Brassica campestris* or swede.

The cultivation and management of these two crops are very similar, but the plants differ considerably in their characters and habits of growth. The turnip is typically in the shape of a flattened globe, from which the leaves spread direct, while the swede is more upright in its growth and carries the leaves at the top of the neck or short stem. The flesh of the roots also varies in being white in most varieties of turnips and yellow in most swedes. The leaf of the turnip is of a light green colour and is rather roughened. That of the swede, on the other hand, is smooth in texture and of a bluish-green colour. The swede grows more slowly than the turnip, and has greater power of resisting frost, and is altogether a hardier crop. Similarly, it suffers less than the turnip from the disease called "finger-and-toe." On the other hand, the swede usually produces

rather lighter crops, though weight for weight the roots have more feeding value. Intermediate between these two species is a class of hybrids, which combine the characters of turnips and swedes, generally resembling the turnip in external appearance but the swede in the texture of the root and feeding properties.

Many varieties of each of these classes are cultivated.

Of the turnip the **Green Round** is perhaps more grown than any other, particularly in the south of England, where it is employed not only in the usual way as a root crop, but also to produce early green food by the growth of tops early in the spring.

The Greystone is another variety, chiefly grown in the south of England, and used for feeding early in the autumn. The upper part of the root of this plant is of a mottled dull purple colour, the lower part being white.

The Pomeranian White is another variety used for very early feeding, and has an entirely white root, often growing to a very large size.

Of swedes the most important is the **Purple-top**, which, as its name implies, has a root of a purple colour. It is a variety better to be relied on than any other on the average of seasons.

The Green-top swede keeps particularly well, and the white swede is grown to some extent, particularly for use in the spring for ewes and lambs or milking stock.

Of the hybrids perhaps the most important is the **Fostertoun.** It is particularly quick and free in its growth, but it does not keep very well.

The Aberdeen Yellow is much grown in the northern districts, and is a very useful variety, owing to its power of withstanding frost and keeping till late in the winter. It also has a remarkable tendency to run to top in the spring. Others might be mentioned, such as the green-top yellow, Dale's hybrid, etc., but these are not of so much importance.

As already stated, the cultivation of swedes and that of turnips are similar and may therefore be considered together. In the rotation they are usually taken between two corn crops, as under ordinary circumstances they are restorative to the soil, as well as allowing of a thorough cleaning of the land. The most suitable soil for turnips is a free-working loam.

They may be grown successfully on very light soils if the climate is moist and plenty of manure be supplied to them. Swedes will grow well on rather heavier soils than turnips. Usually, however, the crop is to be avoided on heavy land, and in dry climates also the bulk of crop is very small and its feeding value inferior. It is essential that the land should be in very fine condition for the sowing of the seed, and rather deep cultivation is an advantage. Autumn ploughing is therefore usual, except in very light soils, or where catch crops are grown before the turnip crop, as is frequently done in the warmer parts of the country. In the spring the land should be ploughed, if necessary; but many prefer to keep the fine mould produced by the frost at the surface of the ground and only stir the soil with the cultivators and harrows, but not to turn it over. Something must depend on the condition of the soil, for if it is very foul it will be necessary to clean it thoroughly, if possible, before putting in the seed, and in such a case one, if not more ploughings must be given in the spring, and a thorough cleaning and working after each ploughing. The land must be worked to a fine tilth and all weeds left exposed on the surface, so as to be killed by sun and wind.

The sowing may be either on the flat or on the ridge, the former system being more common in the south of England, the latter in the north. It is apparently a question of rainfall, however, for where the climate is damp the crop does better on the ridge, but in dry districts sowing on the flat is preferable. If sowing on the ridge is adopted, after a fine tilth has been obtained, the land is ridged up with the ridging plough, and rotten farmyard manure is placed in the furrows between the ridges and covered up by splitting the ridges again with the plough. The seed is sown on top of these ridges, so that the manure is immediately below the plants. Sometimes, instead of this plan, the manure is applied to the land in the autumn and covered by the autumn ploughing, so as to be thoroughly mixed with the soil, and this is usually done where the system of sowing on the flat is to be adopted.

The usual distance apart of the rows in which the seed is sown is from 24 to 27 inches, whether on the flat or on the ridge, but in exceptional cases the distance

may be as much as 30 or even 36 inches. Wherever a very large growth is expected, or where the land is foul, more space is required than where the converse is the case. The quantity of manure used varies very much in different districts and under different conditions, being usually greater in the north than in the south, and of course being greater where the soil is deep or "hungry" than where it is shallow or retentive. In some districts in the north the quantity of artificial manure (superphosphate, bones, etc., phosphatic guano) used is sometimes not far short of a ton per acre, in addition to farmyard manure, though this quantity is of course not a general practice. In the north of England about 8 cwts. of superphosphate or its equivalent of other phosphatic manure are frequently used, and in the south of England 3 or 4 cwts. give the most economical results. The reason for this is apparently that in the north the period of growth of the crop is considerably longer than in the south, and therefore the plant has a better opportunity of making use of the plant food placed within its reach in the soil. As to the quantity of farmyard manure used, this also varies in the same way, ranging from 10 or 15 tons per acre up to 30 tons.

The time of sowing varies with the district, being generally later in the south than in the north. In the northern districts May is the usual month for sowing swedes, and most of the turnip sowing is over by about the middle of June; while in the south the usual seed-time is about a month later than this. In the southern counties, if the seed is put in too early, it is found that the crop is more likely to suffer from mildew, and that there is great risk of the plant running to seed and of the roots becoming cottony in the centre and of small feeding value. The seed is sometimes sown later than the time mentioned above, especially in the south of England, where it is common to put in stubble turnips, that is, turnips sown after a corn crop. Treated in this way they never produce great weight of roots, but are valuable for their tops in the spring, and it is found that turnips sown late in the season have a greater power of resisting the cold of winter, and may be relied upon to withstand any ordinary frost.

The amount of seed sown is usually from 2½ to 3½ lbs. per

acre of swedes, and from 2 to 3 lbs. for common turnips or hybrids. This quantity, small as it appears, is far more than sufficient to provide the number of plants required; but it is necessary to sow a good deal more than is actually required, so as to secure even sowing, and because of the great risk of the destruction of the young plants by drought, or by the turnip fly or other insect pest.

If the seed-bed has been well prepared and the seed is put in in warm weather it germinates very rapidly, and even in the course of a day or two the young plants will appear in rows on the land. The two first leaves of the plant or cotyledons appear some time before the permanent leaves are produced, and it is in this stage of the plant's growth that there is greatest risk of injury from the "fly"; for if the cotyledons are destroyed the whole plant will be killed, and, owing to their very small size, they may easily be cut off by insects. As soon as the permanent leaves are produced the crop is practically safe, but until then there is need for constant watchfulness in case of serious attack. On the other hand, in moist seasons, when the crop grows rapidly, the plants rush into leaf and become crowded in the rows before it is possible to single them. If this happens the plants become weak and spindly, and a full crop cannot be obtained. The best thing to do under the circumstances is to "bunch" the crop by roughly chopping out the rows with the hoe, leaving bunches of plants standing together with intervals between. More chance is then given for the development of the plants, and singling can be carried out afterwards when there is more time.

The singling is a very important matter, and consists in chopping out the plants, leaving single ones standing at intervals varying from about 10 to 12 inches, swedes being usually singled to a less distance apart than turnips, owing to their less spreading habit. If the singling is not done carefully, and if in consequence two plants be left side by side, two small misshapen roots will be produced in place of one good one, and there will be therefore great loss both in weight of crop and in feeding value. In singling the strongest plants only should be left, as these are more likely to produce large, good roots than the weakly plants. Besides the singling and hand-hoeing, which are

usually done at the same time, horse-hoeing is required at least two or three times during the growth of the crop, and in fact it is better to keep the horse-hoe going as long as possible, until the growth of the crop prevents any further working of the land. In this way the soil is kept clean and in a moister condition and better suited for the growth of plants. It is found that by constant horse-hoeing the disease known as "mildew" is prevented to some extent, and in any case a stronger and better growth of plant is obtained.

Generally speaking, turnips are ready for consumption first, followed by hybrids, and swedes are ready last. Part of the crop is usually stored in some way, so as to protect it from the frost, which will otherwise cause a rotting of the roots. The simplest method of doing this, and one followed to some extent in the warmer parts of the country, is to mould up the roots with the ridging plough, so as to throw the soil up about the crowns of the roots, and so give them a covering as a protection from frost. It is a very cheap and quick way of protecting the roots, and serves to prevent injury from any but very severe frosts. This, however, is not enough in the colder districts of the country, and is hardly to be relied on for the whole crop anywhere. The roots are very often stored in small heaps placed at intervals all over the field in which they are grown, for the convenience of feeding the sheep in folding them over the land. The roots are pulled by hand and are rapidly topped and tailed, that is, the leaves and rootlets and earth adhering to the roots are trimmed off. The roots are then thrown into heaps and covered with a little straw, with a layer of earth upon them, the earth being taken out close to the heap, so as to form a kind of gutter all round it. Topping and tailing, as it is generally carried out, is often more than is required, and it must be remembered that all injuries to the root itself increase the probability of its decaying in the heap. It is better, therefore, to cut off the leaves, taking care not to injure the root, and to store the root with the earth adhering to it, for it then keeps fresher and the tailing can be done afterwards, when the heaps are opened for the sheep.

Turnips are also stored in large, long heaps called pits or

caves, in very much the same way, being first topped and tailed, then covered with straw and finally with a covering of earth. In all cases space should be left at the top of the heap for a short time for ventilation, as there is a probability of some fermentation taking place, which will cause the decay of the roots unless this precaution is adopted. Where large heaps have been made, the roots must be carried to the heap, and care should be taken to choose dry weather for the process, so as not to injure the texture of the soil by carting over it when it is wet. As a matter of convenience, the roots, as they are lifted and topped and tailed, are thrown together, four rows into one, so as to allow the carts to pass freely up and down the field without injuring the turnips. Then they are left for a short time on the ground, in order to allow the fermentation spoken of above to take place partially before they are put into a heap, and if there is no fear of frost they may be covered roughly with the tops, which will be sufficient protection for any ordinary frost occurring in the autumn.

The most important insect attacking the turnip crop is the turnip fly or turnip flea beetle (*Haltica nemorum*). It is a small beetle, black or dark brown in colour, with two yellowish stripes on its back, one running down each wing-case. It has powerful legs, which are well adapted for jumping, so that on the least approach of danger or disturbance it can escape. This insect hibernates in any convenient shelter, and in the spring, as soon as the warm weather commences, comes out and lives for the time being upon various plants of the turnip kind, that is, belonging to the natural order Cruciferæ, such as the shepherd's purse, charlock, garlic, mustard, etc. When the turnip crops commence their growth the fly attacks them, and not only itself but its maggots also feed on the leaves. The insect has a short life, only extending over a few weeks in all; but a number of broods may be produced in succession in the year, so that the attack on the crop may go on through the whole season. The most serious damage is done in dry weather, which not only is very favourable to the fly, but diminishes the growth of the turnip. Of course as the greatest harm is done by the fly when the turnip is in its young stages, anything arresting its growth

then will increase the injury done by the insect. To prevent injury from the "fly," thorough cultivation is necessary, so that the plant may be able to make rapid strong growth, and with the same object it is well to avoid ploughing or working the land more than can be helped immediately before sowing the seed, for by doing this it becomes very dry, and there is fear that the plant may not be able to grow rapidly. The destruction of cruciferous weeds is also advantageous, though difficult to effect to more than a partial extent. When the attack has commenced a dressing of forcing manure is an advantage, so as to push on the growth of the plant and particularly to produce leaves, so that the growth of leaf may counterbalance the destruction caused by the insect. Rolling or other disturbance to the insect also has a good effect, as have dressings of lime, soot, sulphur, etc., applied when the leaf is wet. A dressing of paraffin finely sprayed over the crop is also efficacious, and can be applied by means of a spraying machine, such as the Strawsoniser.

The turnip saw-fly (*Athalia spinarum*) is happily of rare occurrence in any large numbers, for when it is found it does enormous mischief to the turnip crop. The caterpillar, which is green or black in colour, feeds on the leaves of the crop, entirely stripping them, and in a few days every plant may be destroyed. Naturally, little can be done to counteract the attack, but it is found that disturbance by driving sheep over the land, or bush-harrowing, or by any other means is advantageous by detaching the caterpillars from the plant when they are in the act of changing their skin, when they are destroyed. Heavy dressings of nitrogenous manures are also of advantage by causing a strong growth of leaf.

The surface caterpillars which attack the turnip crop are those of the turnip moth or dart moth (*Agrotis segetum*), and the heart and dart moth (*Agrotis exclamationis*). These caterpillars are very similar, being large grubs about an inch and a half long, which live in the surface soil near the plants. They feed upon the roots and lower parts of the stems of turnips, cabbages, potatoes, and many other plants. The attack is difficult to counteract in any way, because the caterpillars are too well protected by the soil to be

affected by any dressing applied to the surface. Harrowing and horse-hoeing are found to be useful by disturbing the caterpillars and bringing them up to the surface, where they are destroyed by birds. In some cases, and particularly for garden crops, the caterpillars are hand picked, but this of course is a somewhat expensive method of getting rid of the pest.

The turnip gall weevil (*Centorhynchus sulcicollis*) is a small black beetle which lays its eggs in or upon the root of the turnip, and the maggot, living in the root, causes lumps or swellings, usually called galls. The injury done is not generally very great, but sometimes causes a lodging of water in the root and may thus be more serious. The application of gas-lime has been found fairly efficacious, and is almost the only thing to be done. This attack must not be confounded with the fungoid disease finger-and-toe, though the one is often mistaken for the other.

The diamond-backed moth (*Plutella cruciferarum*) is a small moth very like the clothes moth in appearance. It is not usually of much importance, but occasionally, as in 1891, it does great injury. The caterpillar is green in colour, and spindle-shaped, feeds on the leaves of the plants, living on their under-side. This habit makes them particularly difficult to destroy, for any ordinary application, either dry or liquid, does not reach the caterpillar, because of the shelter which the leaves afford. The most satisfactory results are obtained by brushing over the crop with a light bush harrow, or in some other way, so as to knock the caterpillars off the leaves. Nitrogenous manure, by forcing on leaf growth, is also useful, and heavy rains appear to destroy the caterpillars.

The most important fungoid disease attacking the turnip crop is finger-and-toe or anbury, which is caused by one of the slime fungoids (*Plasmodiophora brassicæ*), which is found in the soil. On obtaining access to the interior of the plant it attacks the cells of the root, causing a misshapen and irregular growth, swellings occurring in some parts, while in others growth is arrested. Finally, it causes the root to decay, and about the same time forms resting spores, in which condition it lives during the winter, either in the soil or in the remains of the plant. The best remedy is an

application of caustic lime or gas-lime to the soil, and on land liable to the attack it is better to avoid the use of superphosphate, for the acid of the manure seems to encourage the growth of the fungus.

It is also very important to keep down cruciferous weeds, as they serve to carry on the infection from one year to another. It is sometimes even necessary to restrict the growth of cruciferous crops, and only take them at comparatively long intervals.

The **mildew** (*Peronospora parasitica*) is also an important fungoid disease affecting turnips, and is nearly allied to the potato disease. The attack is generally most severe when the growth of the crop is suddenly arrested after having been rapid, or sometimes as the result of too early sowing. The use of the horse hoe is a good preventive of the disease, by encouraging a continuous growth and so keeping the plant in a healthy condition.

Mangels

The mangel (*Beta vulgaris*) or mangel wurzel is derived from a useless seaside plant, and has attained its present form by careful cultivation and selection. There are many varieties, differing in their colour and shape.

One of the most important is the **Orange Globe**, the root of which is of a yellow colour, though the flesh is white. It is specially suited for rather shallow or heavy soils.

The Golden Tankard is remarkable for its high feeding value and keeping properties, being rather darker in colour than the orange globe and having yellow flesh.

The Long Red variety is perhaps the heaviest cropper, and is good for deep loams.

Other varieties grown are the **Long Yellow** and **Globe Red**, which, however, are not so important as the other three sorts. By some the red varieties are said to have greater tendency to make stock scour when fed upon them than the yellow, but this does not seem to hold good in all cases.

Mangels are grown in the warmer and drier districts of the country, being found chiefly in the south and east, and comparatively little in the north. They require a consider-

able amount of sunshine, and can withstand drought far better than most other root crops. Large dressings of farmyard manure are usually applied to the crop and are usually spread on the land in the autumn and at once ploughed in. Sometimes, however, the manure is applied in the spring when the land is ready for sowing. In every case ploughing is carried out in the autumn, and in the spring the soil is cross-ploughed and worked to a fine tilth, when the seed is sown either on the ridge or on the flat. The former method is most common, and usually gives the best results. With mangels, however, just as with turnips, it depends very much on the rainfall, for with a very small rainfall the crop succeeds best on the flat.

About 6 or 8 lbs. of seed per acre are usually sown, in rows about 27 inches or rather more apart, in the case of the globe or tankard varieties, or 21 to 24 inches apart where long sorts are cultivated. With the seed, 3 to 5 cwts. of superphosphate are usually sown, or sometimes rather more, and a dressing of 4 or 5 cwts. of salt is also frequently given. broadcasted when sowing the seed, or sown on the land before the final ridging. Nitrogenous manures are also used, and nitrate of soda in particular gives a large increase in the crop. The commercial "seed" consists of a rough husk containing three true seeds, two of which usually produce plants, which thus generally grow in pairs side by side. This is a matter of some importance, for it increases the difficulty of singling properly, and, as in the case of turnips, if singling is not done perfectly it is impossible to obtain good results. Owing also to the thick husk which surrounds the seeds, they are usually very slow in germinating, and will sometimes lie for some weeks in the soil without showing signs of life. To hasten their growth they are sometimes soaked in water before sowing, when, if the seed-bed is warm, and well prepared for their reception, they will germinate comparatively rapidly.

The usual time of sowing is about the middle of April to the beginning of May, and as soon as the plant appears above the ground horse-hoeing and hand-hoeing must be carried out, and if growth be rapid singling should be begun as soon as possible. There is usually little difficulty in getting the mangel crop singled in time, but sometimes

in warm forcing weather the plants become crowded in the rows, and the method of bunching the crop, mentioned in the case of turnips, must be adopted in order to prevent their being weakened. The globe varieties are usually singled to a distance of 13 or 14 inches, while the long kinds may be left at from 10 to 12 inches apart, or sometimes closer. Very wide singling, though productive of large individual plants, and often of great weight of crop per acre, is not an unmixed advantage, for the feeding value of small roots is usually higher than that of very large ones.

Mangels are sometimes sown rather earlier in the season in a prepared seed-bed, and are planted out into their final position when the weather is warm enough for them. In this way some weeks' growth may be gained, and a heavier crop obtained in consequence. Transplanting is also adopted if part of the crop has failed, plants being taken from the rows that are thickest to fill up gaps in those that are thin. The subsequent cultivation of the crop is similar to that of turnips, consisting of frequent horse-hoeing and hand-hoeing. Towards the end of the summer, when further hoeing is impossible, it is a good plan to mould up the rows with the ridging plough, this being found to cause further growth.

Mangels are harvested before severe frosts begin in the autumn, usually some time in October. The symptom of their being ready for taking up is when the leaves wither, at which time the roots should be raised with as little injury as possible, the tops cut or twisted off, and the roots stored in the way already described in the case of turnips. They need even better protection from cold than turnips, and more care must be taken to avoid anything that may cause rotting or decay, because they have to be kept so long, being stored first and used last of the root crops.

Of the insects attacking the mangel crop the most important is perhaps the mangel fly (*Anthomyia betæ*), the maggots of which live in the leaves, eating out the interior and leaving simply the membrane or skin. By depriving the plant in this way of its power of feeding on the air they cause a great loss of weight of produce, and sometimes even destroy the plants. The best method of counteracting the attack is to apply nitrogenous manures to force on as rapid leaf growth as possible.

The surface caterpillars spoken of in connection with the turnip also attack mangels in the same way.

Kohl Rabi

This plant, the systematic name of which is *Brassica caulorapa*, is a near relation of the turnip, but has been developed in a different direction, for while the turnip has a large development of root, the so-called bulb of the kohl rabi is an enlargement of the stem, from which the leaves spring directly. There are two kinds commonly grown—the **Purple-top** and the **Green**—the former of which is hardier, slower in its growth, and later in coming to maturity, being in fact more like the swede, while the latter usually yields heavier crops and is more akin to the common turnip.

The crop is not much grown except in the Fen districts, where it is of considerable importance; but it is very useful and worthy of more extended cultivation, for while it gives as large a return as turnips, it has several advantages over that crop. It is sown earlier in the year, and consequently is less subject to the attacks of turnip fly, while, owing to its earlier seed-time, its use in displacing part of the turnip break, the labour of seed-time is spread over a longer period, and is therefore more easily done. In its cultivation it is almost the same as that of the turnip, excepting that the seed is sown about the middle of April, or the plants may be transplanted from a seed-bed into the field. The crop is ready for storing about November, and the roots will keep very well. For giving to cows the plant is particularly useful, as it does not taint the milk to such an extent as turnips. The diseases of the crop and the insects which attack it are similar to those of turnips.

Carrots

The carrot (*Daucus carota*) is not cultivated to any great extent in this country, and its growth might, with advantage, be extended in some districts. The varieties most commonly grown as farm crops are the **Common Red** and the **White Belgian**, of which the latter yields the larger crop, but of rather coarse quality. Where market gardening is followed

the **Early Horn** and **Italian Early Market** are very much grown.

The carrot requires a fine deep soil, preferably a sandy loam, and it is essential that it should be worked to a very fine deep tilth. The cultivation is usually carried out in the spring, but sometimes the land is previously ploughed in the autumn, so as to expose it to the frost.

The carrot succeeds best where heavy dressings of manure have been applied to the previous crop; but sometimes farmyard manure is applied direct, but if so it should be well rotted, so that it may offer no obstruction to the growth of the carrot. Anything in the soil which does this, whether stones, manure, or any other substance, tends to make the root fork, that is, divide and tend to revert to a fibrous condition. The usual time of sowing is in March or April, and the seed is put in, on the flat, at the rate of 6 or 7 lbs. per acre, in rows 15 or 18 inches apart. In its natural state the seeds are covered with spines, so that they cling together very much and will not run freely in the drill. It is necessary, therefore, to mix them with sand or ashes so as to separate the seeds and allow of drilling. The seed is also slow in germination, so that it is generally moistened before sowing to hasten its growth, and a little barley or oats is usually mixed with the carrot seed before sowing, so that by its quicker growth it may show the lines of drill before the carrots have appeared above the surface. Horse-hoeing can then be carried out and the weeds, which otherwise might check the young carrot plants, kept down. The plants are usually singled to a distance of 6 or 7 inches apart, and the whole cultivation of the crop consists in horse-hoeing and hand-hoeing in the same way as for other root crops.

About the middle or end of October carrots are ready for raising, and they are lifted from the soil with a fork, an operation which requires considerable care to avoid breaking the roots, particularly in heavy land. They are then topped and stored like mangels, which they resemble in their keeping properties. They are sometimes allowed to remain for a time in the soil, because, owing to the small amount of root which projects from the surface, they are little harmed by frost.

Carrots are also grown on a large scale for sale early in the season, when they are quite small, being offered in the market in bunches of two or three dozen. For this purpose they are often sown broadcast, and are always allowed to grow thickly upon the ground with comparatively little singling.

Besides the insects which attack all the common farm crops, such as the wireworm and the leather-jacket, there is one which does serious damage to the carrot, namely, the carrot fly (*Psila rosæ*). The maggot of this fly feeds upon the root, eating its way into its heart and causing the outer leaves of the plant to wither away, and producing patches of a brownish rust colour, which gives the attack the common name of rust. The attack usually shows itself after the plants have been thinned, the disturbance of the soil in the process of thinning apparently enabling the fly to deposit its eggs upon the roots. Dressings of paraffin, salt, gas-lime, etc., are recommended as being efficacious in destroying the insect.

The Parsnip

This plant, the systematic name of which is *Pastinaca sativa*, is but little grown in this country, though it is of very high feeding value, owing partly to the fact that it is troublesome to raise from the ground after growth, and partly because stock do not take to it readily. Almost the only important variety is the **Hollow-crowned Parsnip,** which is almost universally grown. It grows well on moderately heavy land, but it requires a fine tilth, otherwise it is liable to fork and produce no root of value. Like the carrot it succeeds best without any direct manuring, and should therefore be taken after some crop which has been heavily manured. It differs from most of the root crops by succeeding best on a freshly-turned furrow, so the sowing of the seed should take place as soon as possible after the cultivation of the soil has been carried out, the ploughing and sowing being in some cases done on the same day. The seed is drilled in March or April, at the rate of 6 or 8 lbs. an acre, in rows about 12 to 15 inches apart, and the plants are singled to a distance of 8 or 10 inches apart in the row.

The cultivation is similar to that of carrots, and the roots are ready for consumption about the same time. They are, however, commonly left in the ground until they are required, as being buried almost completely in the soil they do not suffer from frost.

CHAPTER XXIII

POTATOES

The potato (*Solanum tuberosum*), though usually classed with the root crops, is actually a tuber crop, the potatoes being in reality a development of the stem and not true roots. The varieties ordinarily grown may be classed into three groups—early, medium, and late. The early and medium sorts are ready for use immediately they are raised from the ground, while the late or main crop varieties improve with keeping. Amongst many others the following varieties may be noted as being extensively grown.

Early Potatoes.—**Myatt's Ash-leaf,** which is very early, rather delicate, and produces only small crops; **Beauty of Hebron,** rather later, but hardier; **Early Puritan** and **Early Rose,** fair croppers, the latter producing tubers of a pinkish tint.

Medium Varieties.—**Renown,** producing very round tubers of good quality; **Reading Giant,** giving large crops, and tubers having shallow eyes and thin fine skins; **White Elephant,** yielding a heavy crop of large tubers, though the plant is rather delicate; and **Abundance** and **Dalmahoy,** both of which are fairly productive.

Late or Main Crop Varieties.—**Magnum Bonum** is very widely grown, produces a good crop of rather long-shaped tubers, which are shallow in the eye, and readily saleable; **Stourbridge Glory,** a large oval potato; **Imperator,** which yields a very good crop of excellent quality; **Victoria,** a moderate cropper; **Schoolmaster,** yielding a fair crop, but of poor quality; and **Champion,** giving a heavy crop, but coarse in quality.

Points of importance in addition to the cooking qualities of the tubers are, the shape, the depth of the eye, deep-eyed sorts being more wasteful in cooking than shallow-eyed, and fineness of skin, all of which affect the saleability of the crop.

Potatoes usually grow best on deep sandy loams, though the soil which produces the best crops will vary according to the season, in some seasons comparatively heavy land being better than the typical free-working soils. The land is ploughed, cleaned, and often cross-ploughed in the autumn, and in the spring it is again ploughed and worked down to a fine tilth. It is then thrown up into ridges or drills about 27 inches wide, and, unless previously applied, farmyard manure is then spread in the furrows, the sets are planted on the manure about 1 foot apart, and the ridges are split so as to cover the sets with the manure, and leave them in the middle of the ridges. This generally takes place in March or April, depending to some extent on the liability of the district and field to a late frost.

Farmyard manure is sometimes applied in the autumn instead of in the spring, as mentioned above, in that case being ploughed in and thoroughly mixed with the soil, instead of being in direct contact with the sets. It is found that the crop is less liable to disease where this is done than where the sets are planted on the manure.

Artificial manures are commonly broadcasted on the land before the ridges are split, superphosphate being employed at the rate of from 5 to 7 cwts. per acre, and sulphate of ammonia or nitrate of soda, preferably the former, at the rate of 1½ to 2 cwts. per acre. On sandy land potash is often deficient, and kainite therefore gives good results, 2 or 3 cwts. per acre being the usual dressing.

The sets consist of whole tubers or parts of tubers, in the latter case the tubers are cut so as to leave at least one eye on each set, the eyes being the points at which growth takes place. Some growers prefer to have more than one eye on a set, so that if one shoot is destroyed there is still a chance of another producing a plant. Other growers, however, cut out all but one eye, so that the whole strength of the set may be concentrated in producing one shoot.

If the sets are cut it is necessary to leave them for some

days before planting, and to dust them over with ashes, powdered gypsum, or other material, so as to heal up the cut surface and prevent the bleeding of the sets—that is, the escape of their juices—which would entail a loss of part of the nitrogenous matter they contain. In choosing potatoes for sets, it is very important that only sound tubers should be used, for if any diseased ones are planted the crop will certainly be affected. About 12 or 14 cwts. of sets per acre are usually used, although under special circumstances rather more than this will be required.

Potatoes are also often grown on the flat, the cultivation being similar to that described above, except that the farmyard manure is always applied in the autumn, and the planting is usually done in the process of spring ploughing, the sets being placed in the open furrow and covered by the next furrow slice turned. Planting usually takes place in every second or third furrow, so that the rows may be at some little distance apart. Sometimes, however, planting is done after ploughing, and the sets are dibbled in by hand. Machines are also now constructed for planting potatoes, and they do the work with great regularity. Whether the crop be grown on the ridge or on the flat the soil is usually lightly rolled with a wooden roller directly after planting, so as to consolidate the soil about the sets. About a fortnight later the soil is sometimes harrowed or chain-harrowed, so as to prevent any crust being formed on the surface of the soil, and also to keep back the growth of weeds as much as possible. Horse-hoeing is also carried out as soon as possible, and when the plants have made some little growth hand-hoeing is also resorted to.

After each horse-hoeing, or sometimes every other one, the soil between the rows of potatoes is thrown up against the plant by means of the ridging plough, or sometimes a potato plough with the hinder tines removed, and this earthing up counteracts the tendency of the horse-hoe to level down the ridges. This alternate horse-hoeing and earthing up goes on as long as possible, until the growth of the haulms is too great to allow of any further working. The final earthing up is then given, and the crop left until the tubers are ready for raising. The crop is ready when the skin adheres firmly to the flesh of the tubers, and, in

the case of the late varieties, when the haulms are withered and dead. Raising may be done in several ways: by hand, which is rather slow and expensive; by the plough or potato plough, the latter being far preferable; or by a potato digger. In any case a large number of hands are required for picking up and collecting the potatoes, and the work can only be done satisfactorily when the soil is in a dry condition, so that the potatoes can easily be separated from the soil. The tubers are put up in heaps similar to those in which mangels are stored, but a good deal smaller, and are covered very carefully to prevent their being affected by frost. In addition to a covering of straw and earth, a thatch is frequently put over the heaps, and sometimes a layer of stable manure, which, by its fermentation, keeps the heap warm.

Early Potatoes.—In districts where the soil is warm, and where frosts late in the spring are rare, early potatoes may be grown, being planted two or sometimes three months before the ordinary kinds. In the earliest districts, as, for instance, the Channel Islands and Cornwall, planting may begin in January, when, if there is any fear of severe frost, protection must be given to the plants by a covering of straw or seaweed. In the districts where the conditions are rather less favourable, the sets are frequently sprouted in boxes before planting. The boxes are just deep enough to take a single layer of sets, and when filled are kept piled up in a shed, which should be provided with some means of heating. The tubers then begin to shoot, and great care is required in the regulation of light and heat in order to get a healthy growth. If too much heat or moisture be supplied, or if the tubers be kept too dark, the shoots formed will be white and brittle, and very liable to injury in planting. The grower always endeavours to regulate the temperature so as to obtain the shoots of a bluish colour, these being tougher than white ones. If sprouting does not take place quickly enough the temperature must be increased, but in that case the sets should be cooled off and exposed to light for about ten days before planting, so as to harden them. When the shoots are about 4 to 6 inches in length the sets are planted, being carried into the field in the boxes so as to as much as possible avoid handling them. They are usually

planted rather thickly in rows, from 1 foot to 18 inches apart, from 1 to 2 tons of sets per acre being employed. This close planting often makes horse hoeing impossible, and the cleaning and cultivation of the land during the growth of the crop has to be done entirely by hand. In the earliest districts part of the crop will be ready for raising by the beginning of May, though the greater part of it will be later than that.

The most important insects attacking the crop are those which have been already described, such as the wireworm, surface caterpillars, leather-jacket, etc.

Of fungoid diseases the most important is the potato disease (*Phytophthora infestans*) which also goes by the name of mould, blight, or rot. This usually makes its appearance some time in July, dark spots appearing on the leaves of the potato plant, which rapidly spread, causing the leaves to wither and die and to decay, giving off a characteristic smell. This is due to the action of the fungus, which, on obtaining access to the plant, forces its way through its tissues, usually attacking the leaf first, and destroying the cells of the plant wherever it goes. It thus prevents the assimilation of carbon from the air, and the formation of the starch which normally forms such a large proportion of the substance of tubers. Eventually the fungus passes down the stems to the tubers, and, if early in the season, causes them to decay, this phase of the disease being usually known as rot. More commonly, however, the crop is approaching maturity by the time the fungus reaches the tubers, and it then hibernates in the latter. In favourable weather the disease spreads very rapidly from plant to plant, by means of small oval bodies called conidia, which are given off from the surface of the plant, and may be carried by wind or in other ways from one plant to another. The production of conidia is particularly rapid in damp, warm weather, thus giving rise to the common belief that the disease is caused by thunder. As methods of prevention the removal and destruction of the haulms are to be recommended. If possible, they should be burnt, or at any rate trodden down into manure. As already mentioned, only sets obtained from a sound crop should be used for seed. The constant moulding up of the crop is found to minimise the effects of

the disease, and, in the case of an attack late in the season, the haulms may be removed before the tubers are ready for lifting. There is in this way a loss in the quantity of the crop, but the disease is prevented from going down into the tubers themselves. If the attack is early in the season, however, this cannot be done, as even if the tubers were sound they would be very small and almost worthless. The coarser and thicker-skinned varieties of potato have usually the greatest power of resisting the disease, and all new varieties recently derived from seedlings are also usually hardier. Heavy manuring of a forcing character, and particularly the use of organic manures, increases the liability of the crop to disease.

During the last few years a dressing known as "bouillie bordelaise" or Bordeaux broth has been largely recommended for preventing or curing the potato disease. It consists of a mixture of 20 lbs. of sulphate of copper, 10 lbs. of slaked lime, mixed in 100 gallons of water, with occasionally an admixture of about 20 lbs. of molasses. This last substance, however, is of no advantage. The lime must be of good quality or more must be used. The dressing is used at the rate of 100 to 150 gallons per acre, and is sprayed over the plant either before the disease shows itself or as soon as possible afterwards. It is important that the under-side of the leaves be sprayed. As the result of experiments carried out by the Royal Agricultural Society in 1891, the following is stated as the general conclusion:—

The general outcome of the experiments appears to be that the *bouillie bordelaise* has not prevented the disease in any of the localities, but that it has decreased the amount of disease in the plots to which it has been applied, and has decidedly increased the yield of tubers.[1]

And in the following year, in the continuation of these experiments, the conclusions arrived at were:—

1. That the dressing with *bouillie bordelaise*, though it does not entirely prevent disease, has a marked effect in lessening the extent to which disease spreads.

2. That associated with the lessening of disease is an almost certain increase of crop, which more than pays for the cost of application of the dressing.

That the best treatment is an early application of the *bouillie*

[1] *Journal R.A.S.E.*, vol. ii. T.S.

bordelaise before disease has made its appearance, and that this should be repeated if the marks of the first dressing have been removed by rain.

That even if delayed until disease comes, a lessening of the spread of disease may to some degree be effected by a late dressing, and the crop, as a rule, will be sufficiently increased to pay for the application.[1]

A number of other experiments have been carried out recently in this and other countries with somewhat various results, but generally pointing in the same direction as the results quoted above.

A common disease affecting potatoes is the scab, which, however, is apparently not due to any fungoid or insect attack. Spots appear on the tubers and gradually spread. The surface of the potato is hard and rough, owing to the death of the cells of the tuber at or near the surface. The depth to which this death takes place varies considerably, and is an important factor with regard to the amount of injury caused. Scab is most common in heavy soils and where large dressings of farmyard manure are employed. The use of sets affected with scab does not seem to induce the disease, and thorough cultivation and deep planting are apparently beneficial.

[1] *Journal R.A.S.E.*, vol. iii. T.S.

CHAPTER XXIV

CRUCIFEROUS FORAGE CROPS

THE green crops other than root crops cultivated commonly in this country may be divided conveniently into two groups: first, those usually classed as forage crops, and second, those used for temporary or permanent pastures. The crops in the first group may be divided into four divisions: (1) Cruciferous, (2) Leguminous, (3) Gramineous, and (4) Miscellaneous Forage Crops. Of the cruciferous plants the most important are the cabbage, rape, and mustard.

The Cabbage

The cabbage (*Brassica oleracea*) is largely grown in this country as food for all kinds of stock. The numerous varieties are best classed as **Open-headed** and **Close** or **Drum-headed** varieties, each of which contains both early and late kinds. There is also the **Thousand-headed Kale**, which has comparatively narrow leaves and is somewhat branching in its habit. By planting these different varieties at different times of the year an almost complete succession of green food can be provided over the whole year, but where the climate is cold the greater part of the crop must be planted in the spring.

Cabbages are usually sown in a well-prepared, sheltered seed-bed, and when sufficiently strong the plants are carefully raised, care being taken not to injure the roots, and any affected with anbury or "clubbing," as it is also called, are rejected. The plants are then taken to the field and put in either with the dibber or with the spade. Some care is necessary to make sure that the planting is properly

sown broadcast on a fine seed-bed. Some well-rotted farmyard manure is commonly applied to the land before sowing, and about 3 or 4 cwts. of superphosphate, though frequently, if the land is in good condition, no manure of any kind is used. If drilled the seed is sown in rows 12 or 15 inches apart, so that a thick growth of the crop may tend to smother the weeds, and save to some extent the cost of horse-hoeing. The seed may be put in in this way any time from the beginning of April until the beginning of August, the best time being perhaps in June. Rape is frequently very usefully grown in this way for tiding over the early autumn, when there is frequently a difficulty in providing food for the sheep before the root crop is ready for them.

Rape is also grown for seed in the Fen districts to a considerable extent, for which purpose the preparation of the soil is similar to that described above, the seed being put in at the end of July or the beginning of August. If the crop grows very rank and strong in the autumn it may be necessary to feed it down lightly with sheep, but it is better to avoid this if possible. The plant flowers in May or June, and will be ready for cutting a month later, the maximum of seed being ripe when the top seed pods are of a dark brown colour. They do not, however, all ripen together, and there is therefore always some loss of seed. After cutting the crop is allowed to remain in the field for a week or two, in order to darken the seed, and at this time a little rain does no harm, merely making the seed a better colour.

Mustard

There are two species of mustard grown in this country, namely, the **Black** or **Brown Mustard** (*Sinapis nigra*) and the **White Mustard** (*Sinapis alba*). The former of these is cultivated for its seed, the latter as a forage crop.

The black mustard is only grown in the Fen country, and it requires a deep loam soil containing a good deal of vegetable matter. The best preparation for the crop is a dead fallow or a crop of potatoes. In the previous autumn farmyard manure is usually applied at the rate of 14 or 15 loads per acre, and the land is ploughed at once to cover it.

A fine tilth is essential for the successful growth of the crop, and must be obtained early enough in the year to allow of the seed being sown some time in April. It is necessary, however, to fix the time of sowing with reference to the climate of the district, for in its early stages the crop suffers greatly from frost.

About 4 lbs. of seed are generally sown, in rows 1 foot apart; but sometimes a much heavier seeding is given than this. No singling is usually carried out, and very little horse or hand-hoeing.

Sown in this way the crop is ready for harvest in July or August, when it is cut carefully by hand, and after drying two or three days in the field is stacked. There is great risk of damage to the seed by damp, particularly if it be stacked before it is dry, for the colour is then spoiled and the seed turns gray. One drawback to the growth of mustard for seed is that a great waste of seed takes place in the process of harvesting, and it remains a long time on the land and is difficult to eradicate, mustard becoming a troublesome weed in succeeding crops.

White mustard, which is grown for forage, is cultivated to a certain extent all over the country, being very useful in certain cases owing to its rapid growth. It may be sown in the spring, summer, or autumn, the autumn-sown being ready for spring consumption, while the spring or summer-sown is ready in eight or nine weeks from the time of sowing.

About 12 to 15 lbs. of seed are commonly sown if broadcasted, or rather less if drilled, and the crop is in any case sown thick upon the ground, so as to keep down weeds as much as possible. A fine tilth is required, owing to the rapid growth of the plant and the smallness of the seed, but generally little or no manure is given. The plant has a disadvantage as a forage crop owing to its bitter taste, so that stock frequently do not take to it at once, but require to have it mixed with other food for some little time. In the case of sheep this constitutes a considerable difficulty, which, however, may be got over by sowing rape and mustard mixed, so that they may be fed off together. Mustard is also used for green manuring, and is useful for this purpose owing to its particularly thick growth. It does not, however, enrich the soil so much as the leguminous plants.

CHAPTER XXV

LEGUMINOUS FORAGE CROPS

THE most important of the leguminous forage crops, apart from those found in pastures, are: Vetches or Tares, Sainfoin, Lucerne, Hop Trefoil, Bokhara Clover, Trifolium, Kidney Vetch, Wood Vetchling, Lupine, Furze, and Serradella.

Vetches

The vetch (*Vicia sativa*) is largely grown in all parts of the country. There are two varieties, the winter and the summer vetch, the only difference between them being in the hardiness of the plant and the rapidity of growth. The winter vetch is suitable for autumn sowing, and is sufficiently hardy to stand during the winter. The summer variety, on the other hand, is sown in the spring, is more delicate and more rapid in its growth.

Vetches succeed best on warm, loamy soils, but they can be grown on almost all varieties of land, and, sown in successive breadths, will yield a supply of green food for a great part of the year. The cultivation of the crop is simple, neither fine tilth nor deep tillage being required, and, as the plant is rather a quick-growing one, it can often be taken as a catch crop, or following some other catch crop. In the south of England winter vetches are got off the land by the beginning of the summer, so that they can be followed by turnips, and often, in later districts, such plants as rape and mustard can be put in after the vetches are consumed. The crop is usually taken after wheat, the stubble being forked over to destroy the couch, and sometimes a dressing of

farmyard manure is spread on the surface. The land is then ploughed to a moderate depth and harrowed, after which the seed is sown, winter vetches in September or even the beginning of October, spring vetches from February onwards. In putting in the crop it is better to sow it in successive small breadths rather than to put in any large area at one time, because in the latter case part will probably grow too mature before the stock can consume it, when the plant will become woody and will lose much of its feeding value. Two or three sowings may be put in in the autumn, and three or even four of summer vetches in the spring. The quantity of seed sown is from 2 to 2½ bushels, and sometimes, particularly in the case of the winter crop, a little oats, rye, or beans is mixed with the vetches, so as to hold up the crop and prevent it lying too closely upon the ground. This allows of a thicker growth, and prevents the plant becoming yellow and rotten at the bottom. There is a disadvantage in using rye for this purpose, viz. that although it is very much liked by stock when fresh and green, it usually shoots into ear before the vetches are finished, and is then tough and pithy, and unpalatable to stock. In some of the southern counties it is customary to broadcast the seed immediately after ploughing, and cover it by harrowing. About 3 bushels of seed is required in this case, but the cost of cultivation is rather less, and very good crops are obtained. Winter vetches frequently suffer during the spring from severe night frosts, particularly when the days are warm, and sometimes from the loosening of the roots of the plant in the soil. Where this latter takes place a rolling or Cambridge rolling early in the spring will frequently save the crop.

The maximum feeding value of the plant is when the flowering is just over and the seed beginning to form, and it is at this time that it is cut for making hay or silage. When it is fed off a commencement must be made before this, or the crop will get woody before it can be finished. When sheep are folded upon it there is often great waste from their trampling down the plant and then refusing to eat it. This may be overcome by cutting the vetches and giving them to the sheep in their racks.

When made into hay the cutting is generally done by

hand to avoid breaking the leaf of the plant, which contains most valuable feeding material. It is rather a difficult crop to dry thoroughly, and is therefore sometimes put up into the stack with layers of straw between those of the hay. For ensilage vetches are variously reported on, some finding them very useful and producing good palatable food, while others find them unsuitable for the process. Possibly the crop is not so suitable for the process as many others that are commonly grown.

When vetches are grown for seed it is necessary that the soil should not be in very high condition, otherwise the plant makes a strong growth of leaf and stem but does not ripen its seed well. Beans should always be mixed in small quantity with the seed when grown for this purpose, so as to hold them up and allow the sun and air to act on the crop more easily, and so to bring about a more even ripening. The cultivation is otherwise similar to that already described, but the plants are allowed to ripen, are tied up together in bundles or sheaves and stooked in the field until they are quite dry, and then carried—preferably on a dull day—with great care to avoid "britting," that is, the opening of the seed vessels and wasting of the seed. The beans and vetches are easily separated in threshing, owing to their difference in size.

Sainfoin

Sainfoin (*Onobrychis sativa*) is a very valuable forage crop for growth on light, dry, shallow soils, particularly if calcareous, and where the subsoil is of a loose, porous nature. On heavy clay soils, or where the subsoil is impervious, the sainfoin is unsuccessful. It grows on the chalk, particularly where a calcareous gravel underlies the soil. It also occurs as an important crop in most of the limestone formations.

The chief point necessary to observe in the cultivation of the crop is that the land must be perfectly clean before the seed is sown, so that the sainfoin may not be choked by weeds, but may obtain possession of the soil and last for a number of years. Deep cultivation is not required; but the soil should be in good condition, so that sainfoin is commonly sown with barley or other corn crop, particularly

after a root crop fed off by sheep. The seed used is usually what is called "milled" sainfoin, that is, seed extracted from the outer pod or husk; but frequently rough or unmilled seed is used, though it does not generally give such good results. If rough seed be used, about 4 bushels per acre should be sown; if milled, 20 or 30 lbs. per acre will be enough. The seed is usually put in some time in March or early in April, and may be drilled or broadcasted; but drilling is preferable, especially if rough seed is used, for it is difficult to cover a large, light seed such as rough sainfoin if it is sown broadcast. The year after the corn crop is cleared the sainfoin is cut to hay, and should be cut rather early in its growth, so as to prevent any exhaustion of the plant by the formation of seed. In this way a stronger root growth is obtained, and there is less fear of weeds choking out the crop. Frequently one cutting of hay is taken each year, and the sainfoin afterwards grazed by sheep or cattle. Manure should be applied every other autumn; sometimes every autumn, according to the condition of the soil and whether the crop is made into hay or grazed. For haymaking it is usually cut when the flowers first begin to open, and is treated just as clover, following the process of haymaking that will be described later on. Rain during the process of making spoils sainfoin hay perhaps even more than clover hay. Usually in the last season, before breaking up the sainfoin, a crop of seed is taken, for till then the formation of seed is to be avoided as being exhausting to the plants, and so making them thinner in their growth. For this purpose the sainfoin is usually fed down in the spring, and is then allowed to ripen its seed, which will be ready for cutting at the end of July or some time in August. It is then cut, preferably when rather damp, for there is then less loss of seed; and it is put into small cocks until dry, when it is carted to the stack. The straw in this case is of little value; stock will eat it, but its composition is poor.

The great difficulty to contend with with regard to sainfoin is its being choked by weeds, and the usual practice is to allow the crop to stand until the weeds become too strong for it. One great point towards preventing this smothering of the crop is to sow pure seed in the first instance, and, particularly where rough sainfoin is used,

great care must be taken to avoid impurities. With milled sainfoin it is comparatively easy both to clean the seed and to detect impurities if they exist, but with rough seed it is more difficult. The commonest impurity of the rough seed is burnet, a plant which will be spoken of later on amongst the miscellaneous plants occurring in pastures. Other weeds which commonly occur in sainfoin leys are various species of brome grass, particularly the soft brome and the sterile brome.

Lucerne

Lucerne (*Medicago sativa*) grows well on deep, dry, medium soils of a calcareous nature, but requires a rather warm climate, as it suffers severely from frosts. It is therefore chiefly grown in Kent and the southern counties, and is seldom, if ever, cultivated in the north of England. It has, however, been experimentally grown with success in the north-western counties, and probably its cultivation might be extended with advantage. It is a deep-rooted plant, and therefore has great power of resisting drought; but for the same reason it requires deep cultivation before sowing, and the subsoiler is frequently used to stir the subsoil and to give the plant a greater range for its roots. A fine tilth, free from weeds, is necessary, and the seed is usually sown in March or April, as soon as there is no fear of severe frost. The amount of seed sown varies from 12 lbs. per acre upwards, the average being perhaps 15 or 18 lbs. if drilled, or 20 to 25 if sown broadcast. Drilling is, however, superior to broadcast sowing, as it allows the crop to be hoed and weeded during its growth, so that the lucerne will stand for a longer time before it is choked by weeds. In the first season after sowing one cutting can be obtained; but it is important never to cut or feed off the crop late in the autumn, or it is more likely to be injured by frost. For the same reason it is well to leave a long stubble in cutting in the autumn, for this protects the roots, sheltering them from the cold. A moderate dressing of farmyard manure is applied in the autumn, and this serves to protect the plant from the cold. In the second and subsequent years two or more cuttings can be taken, though the total quantity of fodder produced will vary

largely with the season. In any case it is of great importance to cut the crop early, for it is thus prevented from exhausting its strength by the production of seed, while the fodder obtained has a higher feeding value. Every year the crop should be carefully weeded in the spring; but in spite of this the weeds will eventually smother the lucerne, and the crop will have to be broken up. If, however, the land is clean to begin with, the lucerne will stand for a very long time.

Lucerne is sometimes cut to hay; but it is not a satisfactory plant for the purpose, as it is difficult to dry thoroughly, and the stems become hard and woody in the process, so that it is distinctly a more valuable plant for feeding green than for drying. The seed is saved during the last year before breaking up the lucerne, and it is treated in the same way as sainfoin, being fed down in the spring and then allowed to ripen its seed. The seed is small, of a yellowish or light brown colour, having a dull surface, and distinctly kidney-shaped. It is important to distinguish between it and the seed of the hop trefoil, which is rather smaller, more round in shape, and shows the tip of the radicle projecting slightly from the surface. Fig. 17 gives an idea of the difference between the two seeds.

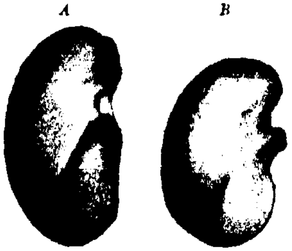

FIG. 17.—*A*, Seed of Lucerne magnified. *B*, Seed of Hop Trefoil magnified.

Hop Trefoil

Hop trefoil (*Medicago lupulina*) also goes by the names of yellow trefoil, black medick, and nonsuch, in different parts of the country. It is really intermediate between the forage crops proper and those which are used for temporary pastures, but is conveniently considered in this place owing to its relationship to lucerne. It grows commonly, and is indigenous in all limestone or chalk districts; but it can be grown successfully on most soils, thriving best, however, on those of a moderately-calcareous nature. In appearance

the plant is very similar to suckling clover and hop clover, but is distinguished from them by the fact of the flower head being one-sided, larger than the suckling clover, but smaller than the hop clover, and a darker yellow than the hop clover; and on close examination the calyx tube of the flower is seen to be split at the upper side and closely haired, while in both the true clovers it is free from hair. When flowering is over, and the seed begins to form, the corolla of the flower falls off, and the seed vessel formed has a twisted appearance, and finally becomes black in colour. The seed is very similar to that of lucerne, and has been already described. It sometimes contains, as impurities, the seed of charlock or field mustard (*Sinapis arvensis*) and that of the rib grass or narrow-leaved plantain (*Plantago lanceolata*), the former being a round seed, rather similar at first sight to the hop trefoil, but distinguished from it by being more rounded, and not showing the projecting tip of the radicle characteristic of the hop trefoil seed; while the rib grass is a dark brown or black seed, deeply furrowed down one side (Fig. 18). The cultivation of the plant is similar to that of clover, which will be found described later on. Its feeding properties are very good, and it is largely grown for sheep feeding, and seems particularly good for fattening lambs. When grown for seed it is treated as already described in the case of sainfoin; but it must be cut when the largest amount of seed is ripe, as the ripening is very irregular, the seeds nearest the root of the plant ripening first.

FIG. 18.—Seed of Rib Grass magnified.

Bokhara Clover

Bokhara clover (*Melilotus alba*), also called sweet clover from its sweet smell when made into hay, is a plant of very little importance. In appearance it is very like lucerne, but very large and strong in its growth, and yields an enormous bulk of forage. It has, however, very little feeding value, owing to the early stage in its growth at which the stem becomes woody and useless, and to the fact that it contains large quantities of cumarin, the material

which gives it its sweet smell, but which has a bitter taste. In consequence of this stock are not very fond of it, even when the plant is young. In its chemical composition, exclusive of the rather large quantity of water it contains, it is remarkable for the amount of nitrogenous matter present; but this is counterbalanced by its other disadvantages. In its cultivation it is similar to lucerne, but is rather more delicate, and must usually be sown rather later in the year.

Trifolium

Trifolium or crimson clover (*Trifolium incarnatum*) is a very important forage crop for growth in the south of England and the Midlands; but it is a delicate plant, and cannot be grown in the north. It also goes by the name of Italian clover, owing to the fact of its having been introduced into this country from Italy. It is an annual plant, giving a single crop in the spring or early summer. It is upright and unbranched in its growth, and the whole plant is closely covered with fine hair. The flower-heads are large and cylindrical, and the flowers are usually of a rich crimson colour, though some varieties are white. Different kinds have been produced to mature at different times of the year, the white varieties usually being later than the red; and this is a great advantage, as it allows of the crop being used with greater convenience in the spring before it gets too far in its growth for economical feeding. It does best on warm, loamy soils, but it will also grow fairly well on heavy land if not too cold. On sandy land it generally only produces a small crop, and is therefore not so valuable. It is usually placed in the rotation as a catch crop before turnips, the seed being sown on the wheat stubble, and harrowed in and lightly rolled. About 18 to 20 lbs. of seed per acre is sufficient, or rather less if a drill be used. Sometimes a little cultivation is given to the soil before sowing, the cultivators and harrows being used; but the first-mentioned plan is the most common, and generally gives as good results as more careful tillage. The plant is ready for cutting or feeding about the end of May or beginning of June, and should be consumed in about three weeks, so that it may not become too woody

before being given to the stock. If the late varieties are grown they will be ready about a fortnight later than the early varieties, and in this way the possible duration of the crop for feeding purposes will be some weeks longer.

The seed is also sometimes sown in February or March where the climate is mild, and it will then produce a crop for soiling or folding as soon as the autumn-sown crop is finished, and even then, in warm districts, there is time to get in a crop of roots after the trifolium is finished. It is sometimes cut to hay; but it is not a good plant for the purpose, owing to the strength and thickness of the stems and the difficulty of handling the crop without losing the leaves, which form the most valuable part for feeding purposes. The feeding value of the hay when made is very considerable. The seed is a large oval one, of a yellowish-brown colour, and with a smooth, glossy surface, distinguishing it from almost all the other clovers (Fig. 19). Occasionally the colour is lighter, varying almost to white. It can usually be obtained fairly pure and of high germinating power, as, owing to its difference in size from that of the other clovers, it is easily separated from them, and, owing to its smooth skin, it is easily cleaned from weed seeds and impurities of all kinds. The crop sometimes suffers considerably in the winter from the attacks of slugs, and the usual methods of preventing damage from this cause may be adopted with advantage.

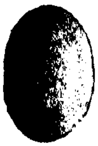

FIG. 19.—Seed of Trifolium magnified.

Kidney Vetch

This plant (*Anthyllis vulneraria*), also called lady's fingers, is not very much grown as a forage crop in this country, but in some districts it has been used with considerable advantage, and on the Continent it has been grown to a considerable extent. It succeeds best on light, dry, sandy soils, but requires a certain proportion of lime for its success. It occurs naturally on chalky soils, and on the thin, brashy land of the oolite formation. In its wild state, however, the plant is not of much value, having only a small proportion of leaf; but by cultivation it has been

so far improved that the amount of leaf is considerable, and the hair, which is so thick on the wild plant, is only present to a moderate extent. This latter point is somewhat important, as it affects the readiness with which stock will consume the plant. As a general rule stock do not care for plants which are thickly covered with hair. In very dry seasons, or in very poor, dry soils, the kidney vetch becomes more like the wild variety, while in moist seasons it becomes stronger and more luxuriant in its growth, and of greater value to the farmer. It is a hardy plant, rarely failing from drought, and being able to withstand any degree of cold common in this country.

The soil should be worked to a rather fine tilth when the seed is sown with the corn crop, as in the case of clover and many other plants. Sometimes, however, it is put in in the autumn instead, on the stubble of the corn crop, in the same way as trifolium. In either case no crop is obtained until the following year; but where the seed is sown in the spring the crop will be ready rather sooner than where it is put in in the autumn. About 16 or 18 lbs. of seed may be drilled and the soil lightly rolled to cover it. If the crop is to be cut continually it is well that this should be done early in the plant's growth; but if the second crop of any one season is to be grazed it is better to cut the first crop just about flowering time, for then the second crop will consist of leaves only, and will have greater feeding value than if there were many flowers produced. The kidney vetch will last for several seasons, but to do this it must be always cut or fed rather early in its growth.

Wood Vetchling

Wood vetchling or Wagner's flat pea (*Lathyrus sylvestris wagneri*).—The cultivated variety of this plant has been developed from the wild wood vetchling, and has been introduced into this country from Germany. In many cases it has yielded large crops of green fodder, though it does not generally produce more than many other of our common forage crops. In feeding value, however, it stands very high, the amount of nitrogenous matter being particularly remarkable. The seed is either sown direct on the land

or in a well-prepared seed-bed, the plants being afterwards transplanted into the field. Sowing in a seed-bed is preferable, though the plant is hardy enough, because of the heavy cost of the seed. For the first one or two seasons the produce is generally small, but as the crop becomes better established much heavier cuttings may be obtained. It is probable, however, that the wood vetchling will never be used except for filling up corners and for growth on comparatively small areas.

Yellow Lupine

The yellow lupine (*Lupinus luteus*) has been recommended at times for growth as a forage plant. Its special value is owing to the fact that it succeeds well on very light, sandy land, too poor for the growth of almost any other crop. In composition also it is of considerable value, containing a good deal of nitrogenous matter. It does not succeed well on chalky land or where there is a chalk subsoil, and on land in high condition it also does badly. It has a very bitter taste, so that most kinds of stock do not eat it readily; but sheep can be got to eat it fairly, and to thrive upon it. It has been found, however, in some cases that poisoning has resulted from the consumption of lupines by stock, though the reason for this is not properly understood.

The appearance of the plant is well known, owing to its common growth in gardens, the leaves being digitate, of a light green colour, and woolly in texture, while the flowers form large spikes of a yellow colour.

The seed is usually sown some time in April, at the rate of about 1½ to 2 bushels per acre, in rows 1 foot apart. For a long time the growth is very slow, but comparatively late in the season it makes greater progress and produces a heavy crop of green food. Farmyard manure is also applied, but only light dressings should be given. During the early stages of the plant's growth horse-hoeing and cleaning of the land are usually necessary, owing to the slow growth of the lupines.

The plant is sometimes grown for seed, but, owing to its very slow growth at first, there is not always time in this country for the seed to ripen in the course of the season, so that it is a risky crop for this purpose.

Furze

This plant is also called gorse or whin. Three varieties of it occur, namely :—

1. The common furze (*Ulex europæus*), which is a hardy, vigorous plant, growing freely on light soils and under very unfavourable conditions of climate. The leaves take the form of spines and are very hard and stiff. This variety flowers in winter and spring.

2. The dwarf or French furze (*Ulex nanus*), which is an autumn-flowering variety, smaller in its growth, and with leaves of a lighter green.

3. The Irish furze (*Ulex strictus*) is comparatively seldom found, and for cultivation suffers from the disadvantage that it must be propagated by sets or cuttings. It is more erect in its growth than the other varieties, and much softer and less spinous in its character.

The common furze, which is the variety principally cultivated, is useful as producing a large quantity of green food on soils too poor or too exposed to grow other useful plants, and it is particularly useful because it is ready for consumption in the winter when green food is usually scarce. It suffers, however, from the disadvantage that stock will not eat it unless it is prepared for them by crushing or chaffing the spines, and this entails considerable labour where the plant is used to any great extent.

The best preparation of the soil is by a ploughing in autumn and thorough cultivation in the spring, so as to obtain a fine seed-bed. The seed may be sown either by itself or with a corn crop, and should be put in as soon as possible after the beginning of April, varying, however, with the climate of the district, it sometimes being necessary to sow as late as May or even the beginning of June. About 12 to 15 lbs. of seed per acre should be sown in drills 1 foot apart, so as to allow of the proper cleaning of the land. Horse-hoeing or hand-hoeing is desirable during the early growth of the plant, until it is strong enough to hold its own against weeds. No crop is obtained the first season after sowing, the first cutting being ready in the autumn of the second season, or some eighteen months after the seed is

sown. The plants are then cut by hand and tied into faggots or bundles for convenience, and the total produce per acre will average about 12 or 13 tons of green food. It is sometimes the practice to cut every alternate row, leaving the rest as a shelter to the young shoots that spring up from the roots after cutting. In the next season the rows previously left untouched are cut, and so on, so that the plants cut are always of two years' growth. This has the advantage of giving shelter to the plants after cutting, but the feeding value of the fodder is rather lower, the plants having become more woody and fibrous, owing to their longer growth.

In chemical composition furze is of fair value, though it contains a high percentage of fibre. Stock, however, like it very much when it is crushed and chaffed for their use, and it is said to give particularly good results as food for milking stock. Special machines are made for chaffing and bruising furze, though the crop is not grown to any great extent.

Furze sometimes suffers from the attack of a Dodder (*Cuscuta*), a parasitic plant similar to that which is injurious to clover. This lives upon the furze, obtaining the food it requires by sucking the juices of the plant and so causing a stunted growth and but little production of leaf.

Serradella

Serradella (*Ornithopus sativus*) is hardly grown in this country except experimentally. In appearance it is rather similar to the vetch, though smaller in its growth and lighter green in its colour. The flowers also are lighter in colour, and of a pink tint. For certain purposes it is a valuable plant, for it thrives well on very light, hungry sands, and yields fodder having a high feeding value. It does not, however, produce large crops, and has the peculiarity of making most of its growth after flowering has commenced, so that it is necessary in using the plant to wait until late in its season of growth before cutting or feeding.

A rather fine seed-bed is required, and the seed is drilled in close rows in the latter half of April or the beginning of

May. Horse-hoeing may be carried out with advantage, so as to prevent the weeds occupying the land while the serradella is young; but when it begins to grow rapidly it will choke out the weeds, and by that time horse-hoeing is impossible. The small bulk of the crop makes it unsuitable for growth on most soils, but on those specially suited for it it will give as good a return as most of the common forage crops. It is often made into hay, which has a very high feeding value.

CHAPTER XXVI

GRAMINEOUS AND MISCELLANEOUS FORAGE CROPS

THE gramineous forage crops, other than those cultivated in our pastures and meadows, are not of such great importance as those belonging to the natural order Leguminosæ. Their feeding value is usually lower, particularly in the amount of nitrogenous matter they contain, though frequently the proportion of carbo-hydrates—that is, starch, sugar, and materials of that kind—is higher than in the leguminous crops. The most important crops coming under this heading are—Maize, Sorghum, Tall Oat Grass, Schroeder's Brome, and Awnless Brome.

Maize

Maize (*Zea mais*) is not well suited for growth in this country, though it has been recommended by several high authorities as a forage crop suitable for at least the south of England. We do not, however, generally have sufficient warmth and sunshine during the summer in this country to cause the free growth that is obtained in other and warmer countries, and the risk of the crop failing altogether is considerable, and makes it an undesirable crop for the farmer to cultivate under ordinary circumstances. It is very liable to injury by late spring frosts, even if they are not very intense, and therefore the seed-time must be deferred till the end of May or the beginning of June, thus allowing only a short period of growth before the frosts of autumn will kill the plant. It is usually, therefore, confined to a not very thick growth of 3 or 4 feet in height, though in warmer

climates accounts are given of crops 8 and 10 feet in height, and the formation of a thick, dense mass of green fodder of considerable feeding value.

The seed is drilled or dibbled on a moderately fine seed-bed, sometimes following one of the early catch crops. The great risk at first is from rooks and other birds, which seem to have a special liking for maize, so that many crops are altogether spoilt owing to their depredations. These may be largely checked by coating the seed lightly with coal tar. When the plants appear above the ground hoeing must be commenced, and the land kept thoroughly clean during the whole growth of the plant. A rough singling is sometimes given them, but often the plants are allowed to stand just as they come up. The crop should be cut rather early if possible, as, if a severe frost occurs in the autumn, it is quite destroyed and rendered of very little value for feeding purposes. If it cannot be used for feeding green it may be made into silage, good results having been obtained with the crop by that process. The plant will usually give good return for nitrogenous manuring, and some superphosphate may also be given with advantage. It also requires a supply of lime, so that if the soil is not naturally calcareous a dressing of lime should be applied some time in the previous autumn.

Sorghum

Sorghum (*Sorghum saccharatum* and *S. vulgare*) is very similar in appearance to maize, but is much smaller and less robust in its growth. In its general characteristics it resembles that plant, and its cultivation is similar. Though the bulk of the crop is not so great as that of maize, its composition is better, as it contains a very large amount of carbo-hydrates, particularly sugar. Like maize, sorghum is a risky crop to grow, as it is very liable to suffer from frost either in spring or autumn.

Tall Oat Grass

Tall oat grass (*Avena elatior*) or false oat, sometimes called by botanists *Arrhenatherum avenaceum*, is cultivated to a considerable extent in America and on the Continent,

but in this country, though it grows in many districts as a common plant of the hedgerows and roadsides, it has not been cultivated to any great extent. In appearance it is a tall grass, the leaves of which in their early stages of growth are of a bluish-green colour, and on close examination prove to be thinly covered with very short inconspicuous hair. Later in the plant's growth the hair is not so easily seen, and the colour of the plant is rather lighter. The seed-head is loose and spreading, the individual spikelets being flattish and having a membranous appearance, and being conspicuously awned. The nodes of the plant are black, and the walls of the stem are peculiarly thin, so that the crop weighs rather lighter than would be expected from its appearance. It produces, however, a useful feeding stuff, and is suited for growth on dry and shallow soils, and in dry climates. Stock do not readily eat it at first, as it has a slightly bitter taste, but they soon get used to this and will then eat it as well as any other grass. The seed has the peculiar membranous appearance that it shows in the spikelet, is rather large, whitish in colour, with a little hair at the base. It somewhat resembles the seed of other cultivated kinds of oat grasses, but is rather smaller than most of them. Its cultivation is similar to that of most of the grasses and clovers, that is, it is sown with a corn crop in the spring, and yields a crop for feeding or cutting in the summer after the corn crop has been harvested. It has a remarkable power of resisting drought, growing freely even in dry seasons.

Schroeder's Brome

Schroeder's Brome (*Bromus Schroederi*) has been introduced into this country in the course of the last few years, though it has not so far been grown to any great extent. It is a very large, coarse-growing grass, tufted in its habit, and forming large, rough, broad leaves which become very coarse and woody when the plant comes to maturity. The stem is very much flattened, and is also of a hard, woody character, except in the early stages of the plant's growth. The seed-head is spreading, but coarse and rough in character, like the rest of the plant. The seeds themselves

are large and flattened, enclosed in a rough husk or "glume," which is usually of a green colour.

As a feeding material Schroeder's brome is valuable in its early stages of growth, up to the time when it becomes woody and coarse, and the large bulk of the plant even when young enables it to be used conveniently thus early, so that the objection to the plant on account of its coarseness is not a vital one.

It may be sown either with a corn crop or by itself in the spring, in the former case usually producing a small cutting of green food in the first season in which it is sown. It has great power of withstanding drought, and is particularly well suited for shallow, dry soils where the better forage crops will not succeed. Owing to its coarse character it is of more value for feeding green than for making into hay.

Awnless Brome

The awnless brome (*Bromus inermis*) is also a plant of recent introduction into this country. In its general character it is similar to Schroeder's brome, and is rather smaller and less coarse. It is not a plant for growth under all conditions, but, like the preceding crop, does well on very dry soils and in dry climates, and produces a greater weight of fodder under those conditions than most other plants. Its treatment is similar to that of Schroeder's brome.

Of the miscellaneous forage crops not occurring in grass land the

Prickly Comfrey

(*Symphytum asperrimum*) is the only one of importance. It is a large, coarse-growing plant, in appearance like borage, to which plant it is nearly related, but much larger and coarser in its growth. It is not a plant suitable for very extensive cultivation, but is very useful for filling up waste corners of fields that would not otherwise be utilised. It is also able to grow under trees and on banks, so that it may frequently be grown where other plants would fail. It succeeds best on moist clays or loams. On dry soils, when it is once fairly established, it does well, and suffers

little from drought, as it is very deep-rooted. It is quite permanent in its growth, and indeed is difficult to eradicate from the land if desired. As a feeding stuff it is very useful where soiling is adopted, and particularly for animals that require to be forced on in condition as rapidly as possible. As a food for bulls, for show cattle, etc., it is well spoken of, and for dairy cattle it also gives good results with regard to both the quantity and quality of milk produced. It has, however, a great disadvantage in the roughness and coarseness of the leaves, for even when these are cut quite young, stock will not take them readily at first, but when once accustomed to the food they eat it with great relish. At first, therefore, they may be encouraged to eat it by sprinkling a little meal over the comfrey when it is put in the mangers, the meal being gradually discontinued as the animal gets accustomed to the fodder.

The plant is usually grown from sets, that is, pieces of the large, fleshy tap-root. These are best planted in sheltered beds in the autumn, when growth commences and plants are produced which will be ready for placing out in the field in the spring. They are usually planted out about 2 feet apart in each direction, or sometimes rather less, and during the first year they will yield one rather small cutting; in subsequent years three or sometimes four cuttings. At first a great deal of hoeing and cleaning of the land will be required, but when the plant grows strong it will choke out all weeds. It is desirable, however, to prevent the roots from spreading through the soil, so that hoeing is required at intervals in order to cut back the young, spreading growth which threatens to fill up the spaces between the original plants. A dressing of farmyard manure is usually applied in the autumn. The produce may range from 30 to 50 tons of green food per acre in the course of the season. Sometimes much larger returns are obtained, though occasionally, under unfavourable conditions, they will be rather smaller. It is, however, not uncommon to obtain 20 tons at one cutting. It is very important in using the crop to cut it early in its growth; if flowering is allowed to commence before cutting the plant becomes very woody, and stock will refuse it, so that there will be great waste in consequence.

CHAPTER XXVII

GRASSES

In considering the grasses of our pastures and meadows it will be convenient to include amongst them not only those which are desirable, but those which are weeds both of grass land and arable. In the following account of the different species no attempt is made to describe the finer botanical distinctions of structure, the descriptions being of the characters which may be easily distinguished without special training.

The grasses are all alike in their general structure, having a root consisting of a number of fine fibres, and a hollow upright stem with nodes or knots at intervals from which the leaves spring. The leaves consist of two parts, namely, the sheath which enfolds the stem, and the blade or free part. At the junction of the leaf and blade there is a small white membrane called the ligule, which is partly wrapped round the stem, and possibly helps to support the sheath by holding it in its place. The ligule is of some importance in distinguishing between the various species of grasses, and is one of the characters which should always be observed for that purpose. The flowers of grasses are always in what are called spikelets, each of which consists of one or more commonly several flowers, enclosed in two outer coverings or glumes, though sometimes only one glume is present. These spikelets may be carried at the ends of the branches of the main stem, making a spreading seed-head as in the case of oats, or they may be set directly on the central stem as in the barley plant. Each individual flower or floret consists of two outer coverings, called pales,

which enclose the male and female organs of reproduction, which are similar to those of other flowering plants. There are usually three stamens or male organs, though in the case of one of the British species there are only two. The "seeds" of most grasses consist of the true seed with the pales adhering to it, though in some cases the true seed or what the botanist calls the caryopsis is obtained, and in other cases the so-called seed consists of the entire spikelet, glumes, pales, and fruit.

Grasses are either annual or perennial, the former being of little value to the farmer. Annual grasses are those which germinate, grow, produce flower and seed and die in the course of one season, every stem producing seed. A perennial grass, on the other hand, forms each year, besides the main stem producing flower and seed, a number of stems bearing leaves only, and these in their turn become flowering stems in the following season, while the original principal stem dies away. The root in these grasses is permanent, though the individual stem dies when it has formed seed.

The following is a short description from an agricultural point of view of the principal grasses of importance to the farmer, but it is not intended in any way as a complete list of British grasses.

Sweet-scented Vernal Grass (*Anthoxanthum odoratum*). This grass produces only a small amount of leaves, the blades of which are slightly haired towards the base. The seed-head is usually compact and small, though where the conditions are favourable to the growth of the plant it becomes slightly spreading at the base. It is of a yellowish or brownish colour when the seed ripens, the glumes having a membranous appearance (Fig. 20, No. 1). The seed is of a dark brown colour, thickly haired, and with two awns, one of which is twisted. It is a good deal adulterated with that of the annual vernal grass (*Anthoxanthum puellei*), which is a worthless weed. The seed of this plant is very similar to that of the sweet-scented vernal, but it is rather lighter in colour, and may be distinguished by the fact that the glumes are serrated at the end or top, and entirely cover the seed they enclose. In sweet-scented vernal, on the other hand, the end of the glumes is not serrated, and their

edges do not overlap completely, so that the dark brown, shining seed can be seen within (Fig. 21).

This grass is not of much importance, although very common. It grows principally on rather moist, rich soils, but also occurs to a great extent on moorlands, where, however, it only makes small growth and is of little value. Under no conditions is its growth very large, and the advantages claimed for the plant are not so great as is usually supposed. It is early in flowering, producing its flower-heads first of the common grasses, but it does not produce the greater part of its leaves till considerably later in the season, so that, though an early grass in flowering, it is not particularly early as regards the food supply for stock, and indeed the second crop is generally more valuable than the first. It is also generally claimed for the plant that it has a special value owing to the scent it gives to hay when present in any considerable quantity, and it certainly is one of several grasses that have this property. But the sweet-smelling substance, cumarin, which it contains is bitter in flavour, and consequently stock are not specially fond of sweet-scented vernal grass. It is, therefore, a plant that should not be sown to any great extent in laying down permanent pastures, and it is unsuited for rotation mixtures, owing to the slowness with which it arrives at its maximum development.

FIG. 21.—Seed of Sweet-scented Vernal Grass magnified.

Mat Grass (*Nardus stricta*).—This is a small, unimportant grass. It has a very narrow, wiry leaf and grows in close tufts, sending up a number of seed-heads. Stock will seldom eat it unless compelled to do so by hunger. It generally occurs only on moorlands and heaths, and on poor, sandy land if wet or even liable to flood. After drainage or any attempt at improvement of the soil the mat grass usually disappears.

Meadow Foxtail (*Alopecurus pratensis*).—At first sight this plant is rather similar to the sweet-scented vernal grass, the seed-head being in the form of a cylindrical spike, but being of a light silvery green colour and of a soft, downy character, owing to the presence of soft awns attached to the spikelets (Fig. 20, No. 2). The root of the plant is less fibrous than that of most grasses, and from the top short, creeping stems or stolons spring, from the ends of which rise the upright stems. This causes the plant to have a loose habit of growth, and prevents it from having any appearance of forming close tufts. In the young plant the base of the stem is white in colour, but gradually darkens as growth proceeds, until it is almost black. The blade of the leaf is of a darkish green colour, slightly ribbed on the upper surface, and the ligule is rather conspicuous, though blunt at the point.

FIG. 22.—Seed of Meadow Foxtail magnified.

The seed (Fig. 22) consists of the whole spikelet, the outer glumes remaining attached to the pales and fruit. It is rather flattened in shape, often being slightly concave on one side and rather convex on the other. In colour it is pale green, and is thickly covered with soft hair, and projecting from the interior of the glumes is an awn, which is slightly bent after the fertilisation of the flower has taken place. This seed is very commonly adulterated with that of the Yorkshire fog (*Holcus lanatus*), which is, however, rather smaller, of a whitish colour, less haired, and with no conspicuous awn, and with two seeds contained within the enclosing glumes (Fig. 23). It was also very common at one time to substitute for the seed of the meadow foxtail that of the slender foxtail or black bent (*Alopecurus agrestis*), which is a troublesome weed on heavy land, and is quite worthless as a pasture plant. The seed of the black bent is rather smaller, not quite so flattened, is of a

yellowish-brown colour, and is very little haired. The slender foxtail seed is more commonly substituted for the meadow foxtail than mixed with it. A common impurity occurring accidentally is the seed of the tussock grass (*Aira cæspitosa*). This is a very small seed, and with a marked tuft of stiff hair arising from its base. Owing to the fact that tussock grass ripens its seed later in the year than meadow foxtail it rarely germinates freely, even when it occurs as an impurity in the foxtail seed.

Meadow foxtail is suitable for growth on moist, deep, rich soils, particularly on heavy land. On dry, poor soils it gives very little produce, and in a short time dies out. It is a very hardy plant, and produces its flowers early in the season, sometimes at the end of April, and is also amongst the earliest of the grasses in producing a large leaf growth. It forms a large proportion of many of the best pastures of the country, and should be included in all mixtures of grass seeds for laying down heavy land to permanent pasture. When used for haymaking it should be cut early in the season, as it produces a very large aftermath or second crop.

FIG. 23.—Seed of Yorkshire Fog magnified.

Stock eat it very readily, and it yields a large proportion of leaf compared with its stem. It is not suitable for growth in rotation except for leys for a number of years, and it is rarely grown except mixed with other plants. Sometimes, however, for the production of seed it is cultivated by itself. The seed ripens irregularly, the upper part of the seed-head being ready before the lower, and it is consequently impossible to harvest the crop without considerable loss of seed. Commonly the seed is stripped from the plant by hand, but, gathered in this way, a great deal of unripe seed is mixed with the ripe, and in consequence the germinating power of the sample is very low. When it has been stripped in this way, the seed must be carefully dried, being put in a thin layer in a dry place and turned at frequent intervals until thoroughly dry. If this is not done the seed will heat and its vitality will be destroyed.

Slender Foxtail (*Alopecurus agrestis*), the seed of which has been described above, is a common plant in hedgerows and a weed in arable fields. In pastures it is usually only found in dry, poor soils. The seed-head is similar to that of the meadow foxtail in character, but is dark in colour, very thin, small, and is harder to the touch.

Floating Foxtail (*Alopecurus geniculatus*) is rather similar to the meadow foxtail, but has the character of bending at each knot of the stem, thus acquiring its systematic name. It is also sometimes called "kneed water grass" for the same reason. It grows well in damp places or in places which are at least sometimes very wet. It is very suitable for growth in water-meadows, where it produces a fair amount of fodder of good feeding value.

Timothy or Meadow Cat's-tail (*Phleum pratense*).—At first sight this plant is often mistaken for meadow foxtail, having a flower-head of the same cylindrical form, but on examination it is found to be free from soft hair, and to be of a harsh, bristling character, quite different from the foxtail (Fig. 20, No. 3). The ends of the glumes are furnished with short, stiff bristles, and the spikelets stand out almost at right angles to the central stem, thus giving a particularly rough feeling to the seed-head. Sometimes a tuberous development takes place at the base of the stem, particularly in dry seasons or in dry soils, and plants exhibiting this peculiarity have frequently been classed as a distinct species. The leaves are of a light green colour, in dry seasons or in dry soils frequently with a slightly bluish tint. The blade is very slightly ribbed on the upper surface and has no keel, the "keel" of a blade of grass being the strongly-marked rib that is usually found forming a projection on its under side. The plant has a peculiar habit of growth, distinguishing it from most other grasses, for the leaves rise obliquely into the air, and do not generally droop or curl over as most blades of grass do (Fig. 20, No. 3).

The seed (Fig. 24) is a very small one, of a light silvery colour, and weighs very heavy in the bushel. It is sometimes adulterated with the seed of Yorkshire fog from which the outer glumes have been removed. This adulteration, however, can be detected by the presence of a short hooked awn attached to the top of the seed of Yorkshire fog. Gray

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FIG. 28.—Seed of Yorkshire Fog magnified.

Stock eat it very readily, and it yields a large proportion of leaf compared with its stem. It is not suitable for growth in rotation except for leys for a number of years, and it is rarely grown except mixed with other plants. Sometimes, however, for the production of seed it is cultivated by itself. The seed ripens irregularly, the upper part of the seed-head being ready before the lower, and it is consequently impossible to harvest the crop without considerable loss of seed. Commonly the seed is stripped from the plant by hand, but, gathered in this way, a great deal of unripe seed is mixed with the ripe, and in consequence the germinating power of the sample is very low. When it has been stripped in this way, the seed must be carefully dried, being put in a thin layer in a dry place and turned at frequent intervals until thoroughly dry. If this is not done the seed will heat and its vitality will be destroyed.

Slender Foxtail (*Alopecurus agrestis*), the seed of which has been described above, is a common plant in hedgerows and a weed in arable fields. In pastures it is usually only found in dry, poor soils. The seed-head is similar to that of the meadow foxtail in character, but is dark in colour, very thin, small, and is harder to the touch.

Floating Foxtail (*Alopecurus geniculatus*) is rather similar to the meadow foxtail, but has the character of bending at each knot of the stem, thus acquiring its systematic name. It is also sometimes called "kneed water grass" for the same reason. It grows well in damp places or in places which are at least sometimes very wet. It is very suitable for growth in water-meadows, where it produces a fair amount of fodder of good feeding value.

Timothy or Meadow Cat's-tail (*Phleum pratense*).—At first sight this plant is often mistaken for meadow foxtail, having a flower-head of the same cylindrical form, but on examination it is found to be free from soft hair, and to be of a harsh, bristling character, quite different from the foxtail (Fig. 20, No. 3). The ends of the glumes are furnished with short, stiff bristles, and the spikelets stand out almost at right angles to the central stem, thus giving a particularly rough feeling to the seed-head. Sometimes a tuberous development takes place at the base of the stem, particularly in dry seasons or in dry soils, and plants exhibiting this peculiarity have frequently been classed as a distinct species. The leaves are of a light green colour, in dry seasons or in dry soils frequently with a slightly bluish tint. The blade is very slightly ribbed on the upper surface and has no keel, the "keel" of a blade of grass being the strongly-marked rib that is usually found forming a projection on its under side. The plant has a peculiar habit of growth, distinguishing it from most other grasses, for the leaves rise obliquely into the air, and do not generally droop or curl over as most blades of grass do (Fig. 20, No. 3).

The seed (Fig. 24) is a very small one, of a light silvery colour, and weighs very heavy in the bushel. It is sometimes adulterated with the seed of Yorkshire fog from which the outer glumes have been removed. This adulteration, however, can be detected by the presence of a short hooked awn attached to the top of the seed of Yorkshire fog. Gray

sand is also sometimes added, and can only be detected on careful inspection, owing to its similarity in colour. A number of weed seeds occur as impurities, such as the sheep sorrel (*Rumex acetosella*), which has a small, glossy brown or yellow seed, angular in shape, and pointed at each end. In size it is about the same as the seed of timothy. The seed of the clover dodder (*Cuscuta trifolii*) also occurs, as does the seed of the field scorpion grass (*Myosotis arvensis*). The colour of the timothy seed is important, for if dark it indicates that it has been injured by the weather in the process of harvesting, and a smaller percentage of seeds will usually germinate than in samples of a bright silvery tint.

FIG. 24.—Seed of Timothy magnified.

The plant grows best on heavy clays, and on land in high condition. It is a useful plant both for permanent pastures and for rotations, and can also be used for irrigation purposes. Timothy, being rather tufted in its habit, however, is best grown with other smaller plants to fill up the intervening spaces. It flowers late, and should be cut about the time of flowering if it is to be made into hay. The hay produced is then of good quality and fetches a high price in the market. If allowed to get over-ripe it becomes wiry and of low feeding value.

Fiorin or Creeping Bent Grass (*Agrostis stolonifera*).—This plant is distinguished by its long stolons, which are found either on the surface of the ground or just below it. At the nodes of these stolons roots are formed, and the plant spreads all through the surface soil, sending out stems into the air at intervals. The other characters of the grass vary very much, according to the conditions under which it grows. The leaves are distinctly ribbed on the upper surface and of a hard, rough nature, particularly in dry soils. The ligule is long and sharp-pointed. The flower-head is branching and very fine and feathery in its appearance, owing to the small size of the spikelets, and is usually of a whitish colour, tinged with red or violet (Fig. 25, Nos. 1 and 2). The seed is the smallest of any of the cultivated grasses. A common method of adulteration is by mixing with the seed a large amount of the glumes or chaff obtained from the plant itself. There is also often great difficulty in obtaining

FIG. 25.—*1*, Fiorin, closed after flowering. *2*, Fiorin, at the time of flowering. *3*, Tussock Grass.

the true seed of fiorin, the seed of brown bent (*Agrostis canina*), marsh bent (*Agrostis alba*), and the common bent (*Agrostis vulgaris*) being often substituted. The brown bent seed is darker in colour and has an awn rising from the back of one pale. The seeds of the other two species of grass seeds are practically similar to that of fiorin. The seed of the tussock grass (*Aira cæspitosa*) also occurs as a common impurity, but is much larger than the fiorin seed, and is distinguished by a strong awn rising from the base of the seed, and by the tuft of short, stiff hair already described.

The true fiorin is a useful plant on moist soils, particularly if light in character. It will also grow well on clays, though it cannot extend so freely through the soil as in light land. It is particularly useful as making its growth both early in the spring and late in the autumn, so that in pastures it lengthens the time during which grazing may be carried out. In feeding value it stands well, and for haymaking it is also useful for cutting rather late in the season. The flowering time of the plant is usually in July or early in August.

In arable land, particularly in moist sands, fiorin is often a troublesome weed, owing to its habit of creeping through the surface soil, and it is very difficult to eradicate. It occasionally goes by the name of "couch" or "twitch." Many other varieties of grasses are also sometimes troublesome in the same way.

Owing to the common practice of substituting seeds of less valuable plants for those of fiorin the course is sometimes followed of growing plants from sets, or pieces of the creeping stolons 2 or 3 inches in length. These may be sown in a moderately fine seed-bed, and rolled in, when they will readily take root.

Brown Bent (*Agrostis canina*) is among the worthless plants occurring frequently on moist moorlands. It produces a very small amount of fodder early in the season, but is incapable of producing food for stock in times of drought.

The Common Bent Grass (*Agrostis vulgaris*) grows in the same way as fiorin, forming creeping stems which run through the surface soil. It is not, however, so valuable

as fiorin, producing less food for stock, though it begins to grow early in the season. This grass also goes by the name of "couch" or "twitch" in some districts, from its creeping habit of growth and its occurrence as a weed.

The Marsh Bent (*Agrostis alba*) grows in the same way as the common bent and fiorin, but only occurs in meadows and pastures. It also frequently goes by the name of couch, not being commonly distinguished from the other creeping plants, having the same habit of growth.

Tussock Grass (*Aira cæspitosa*), also called tufted hair grass, razor grass, hassocks, bull-faces, rough-caps, and a number of other local names.—This plant grows in strong, rough tufts which greatly disfigure and injure the value of grass land in which they occur, because they interfere with mowing and are so coarse that stock will not graze them down. The plant is therefore a weed, and should be rejected wherever it occurs. The flower-head is wide and spreading, the spikelets being very small, so that the whole has a very feathery, light appearance (Fig 25, No. 3). In height it may vary from 18 inches, or less, to 3 feet or more, according to the soil and conditions. It flowers rather late in the year, after most of the cultivated grasses, but this, though an advantage by preventing to some extent the mixing of the tussock seed with that of other plants, often enables the plant to mature its seed after the land has been cut to hay early in the summer. The whole plant is very rough on the surface, both stem and leaf being furnished with projections or teeth, and this, together with the inferior flavour of the grass, prevents stock from eating it. The leaf-blade tapers for the greater part of its length, and if held up to the light exhibits more clearly than in any other common grass clear white lines running parallel to one another from end to end.

Tussock grass occurs chiefly in wet, undrained land, but when once it is established mere drainage is not generally sufficient to eradicate it, and it is necessary to cut out the tussocks or tufts of the plant several times before the weed will be got rid of. Another plan sometimes adopted is to sprinkle the tussocks with salt, and cattle will then eat the tufts close down to the ground in order to obtain the salt. This plan pursued for several years will frequently diminish or eradicate the pest.

The Wavy Hair Grass (*Aira flexuosa*).—This is a much smaller plant than the tussock, and has small, narrow leaves, which, however, are too short and too few to be of any importance to the farmer. The seed-head is loose and drooping, the spikelets being rather larger than those of tussock. They are also glossy, carrying a distinct awn, and often of a red or purplish colour, as is also the stem. The plant is chiefly found on dry, upland pastures, and in shallow, rocky soils, but in any situation is of very little importance. Sheep, however, eat it readily, so that where it grows naturally, and other better plants cannot be cultivated, it is deserving of attention.

Yorkshire Fog (*Holcus lanatus*) or soft meadow grass.—This plant, which occurs very generally in meadows and pastures, grows in close tufts of soft, drooping leaves from which the flower-heads rise, the latter being branching and soft in appearance, of a whitish or slightly purplish colour. (Fig. 26, Nos. 1 and 2). The stem is hairy, except on the upper part, the nodes being almost free from hair. The root is fibrous, having no tendency to creep, and the leaves are thickly covered with rather short hair, giving a whitish appearance to the plant, and making the blade when handled feel almost like a thin piece of velvet. This close hairing, however, is a great disadvantage, as it prevents stock from eating the plant readily. The seed, which has been already described (see Meadow Foxtail), consists of the entire spikelet, two true seeds being usually contained in the glumes. The upper one of these is very frequently infertile, and is always awned with a hooked awn, this serving as a distinction between the Yorkshire fog and other plants of the same genus.

Owing to its strong habit of growth and to the fact that stock rarely eat it unless compelled to do so by hunger, this plant, if once introduced into a pasture, is almost always able to produce large quantities of seed, and so tends to spread and choke out other better plants. There is, however, sometimes a prejudice in its favour, owing to the quantity of its produce, particularly on light, sandy soils or marsh lands, where it grows naturally. In pastures, however, this great show made by the plant is to a great extent due to the refusal of stock to eat it. When grown on deep, moist soils, the Yorkshire fog improves somewhat in its

FIG. 26.—*1*, Yorkshire Fog, closed after flowering. *2*, Yorkshire Fog, at the time of flowering. *3*, Rough-stemmed Meadow Grass.

character, forming larger and more succulent leaves, and not being so thickly haired. The hairing on the leaf is a natural contrivance for preventing the plant giving off water from its surface to a great extent, and so fits it specially for dry soils and seasons; but in moist surroundings the hair is not required, and therefore is not produced so plentifully. It is an almost universal rule that a grass fully haired can grow well without very much moisture.

Creeping Soft Grass (*Holcus mollis*).—In general appearance this plant is similar to the Yorkshire fog, but usually has a smaller, lighter seed-head, which is produced later in the year, has very marked hairing on the nodes of the stem, and is rather less thickly haired on the leaf. The root, as the common name of the plant implies, has a creeping tendency, sometimes extending very rapidly through the soil, though in heavy land, particularly if very dry, it only grows slowly. The seed is similar to that of Yorkshire fog, but is distinguished by the awn carried by the upper seed of the spikelet being knee-bent, but not hooked.

Smooth-stemmed Meadow Grass (*Poa pratensis*), also called the meadow poa and blue grass.—The flower-head of this plant is light, branching, and feathery, the spikelets being very much compressed or flattened, usually containing three or four flowers. The stem, as its name implies, is smooth, and the plant has a creeping habit of growth, extending widely through the surface soil by means of stolons. This has the effect of exhausting the surface soil, and tends to choke out other plants growing with it. The blade of the leaf is rather flattened, of the same width for almost its whole length, with a rounded point and slightly rounded base. It is rather thick in texture, and is not ribbed in any way, but is marked with two median lines or grooves running side by side down the middle of the leaf, this occurring in all the genus Poa. The uppermost sheath on the stem is much longer than the blade of the leaf it carries. The ligule is short and blunt-pointed.

The seed is very small and flattened, carrying, chiefly towards the base, a little short hair on the veins of the lower pale, principally on the middle and marginal veins. This hair is very inconspicuous, and can only be detected with a magnifying glass (Fig. 27, No. 1).

The smooth-stemmed meadow grass grows best on rather light, dry soils, but is found more or less commonly everywhere. Its tendency to choke out other plants in the pasture, which has been already referred to, is a disadvantage, as the best pastures usually consist of a number of different plants well mixed together. The amount of produce and the feeding value also are not particularly high. Both leaves and flowers, however, are produced early in the year, which is an advantage for pastures, but for haymaking the early flowering is a disadvantage, as the seed is ripe and the plant exhausted before the other grasses are ready for cutting.

FIG. 27.—1, Seed of Smooth-stemmed Meadow Grass. 2, Seed of Rough-stemmed Meadow Grass, both magnified.

Rough-stemmed Meadow Grass (*Poa trivialis*).—At first sight this plant is very similar to smooth-stemmed meadow grass, but the flower-head is finer and not so spreading as that of the latter (Fig. 26, No. 3). The stem is slightly rough, and the root is fibrous, with no tendency to send out stolons through the surface soil. The leaf is a thin one, usually folded rather closely down the mid-rib, tapering for almost its whole length to a fine, sharp point, very glossy and shining on the back, smooth, but with the two median lines on the face, and with a very long, thin, sharp-pointed ligule. In this case, as in that of the smooth-stemmed meadow grass, the uppermost sheath is a good deal longer than the leaf it carries. The seed is very similar to that of the smooth-stemmed meadow grass, but at the back of the seed there is hair only on the median vein and the pale, and at the base of the seed a few long, fine hairs are usually found, which, though very fine and difficult to see, except with a magnifying glass, cause the seed to adhere to any rough surface on which it may be placed, so that a sample may be conveniently distinguished by the way in which the seeds will cling to the end of a piece of wood or pencil put into it, the individual seeds hanging by these long hairs (Fig. 27,

rocky. Stock will eat it amongst other plants, but it is of no agricultural value, owing to the very small bulk of its produce. A smaller species, the lesser quaking grass (*Briza minor*), occurs in the south-west of the country, and is distinguished from the common quaking grass most easily by the ligule, which is long and sharp-pointed. This last species is not, however, indigenous in this country.

Cocksfoot (*Dactylis glomerata*).—This is one of the most common of the useful grasses occurring in pastures and meadows. The seed-head is branching, the spikelets being set in dense masses at the ends of the branches, the whole head being somewhat one-sided (Fig. 28, No. 1). The stem is rather rough, and indeed the whole plant, except in its early stages of growth, is coarse and rough in character, thus getting the name rough cocksfoot, by which it often goes. The base of the stem is particularly flattened, and is surrounded with a loose, withered-looking sheath, which gives an untidy appearance to pastures containing large quantities of the grass. The leaf is rather thin, smooth, but not in any way shining, and very closely folded down the mid-rib. As the plant becomes older, the leaf opens slightly, but it still has the marked folding down the mid-rib, and a distinct keel on the under-side. The ligule is large and conspicuous, and jagged at the point. The seed is easily distinguished, being whitish in colour, and very much keeled at the back. It is also slightly curved towards the point, and is frequently slightly awned (Fig. 29). It is commonly adulterated with the seed of perennial rye grass, meadow fescue, tall oat grass, and hard fescue.

This grass grows best in rather moist soils of a medium or heavy character, and in such land is liable to choke out other plants in a pasture, owing to its very strong habit of growth. It is therefore important in laying down land to permanent pasture to avoid sowing too much cocksfoot if the soil is suitable for that grass. On dry soils, however, where it is not able to make such strong, rank growth, it may be usefully employed to make up a large proportion of the sward. Although so coarse and rough in appearance, if it is consumed early in its growth it has a very high feeding value, and stock will eat it readily, but as it matures it becomes very woody, and animals will refuse it if possible.

Fig. 28.—*1*, Cocksfoot. *2*, Crested Dog's-tail.

Special care should therefore be taken to keep it closely grazed, or, if it is made into hay, to cut it early in its growth. It is, however, better fitted for grazing than for cutting. It produces a considerable number of leaves early in the season, and indeed will frequently continue its growth almost all through the winter. This is perhaps partly due to the shelter given to the roots by the sheaths about the base of the stems. Owing to its strong habit of growth it will succeed fairly well under trees, and almost always where trees occur in grass land cocksfoot will be found forming the greater part of the turf under their shade. It is therefore sometimes called orchard grass, owing to its common occurrence in orchards.

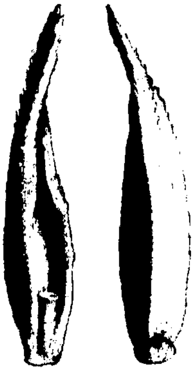

FIG. 29.—Seed of Cocksfoot magnified.

Crested Dog's-tail (*Cynosurus cristatus*).—This is rather a small grass, which produces a number of fine stems, carrying compact seed-heads of a spike-like nature (Fig. 28, No. 2). It is rather tufted in its growth, the base of the stem is of a yellow colour, and the leaves springing from the root have a crisp texture, are stiff, and usually curving upwards, are broad at the base, and taper rapidly to the point, and have very distinct ribbing on the face, while the back is smooth and shining. The seed is usually small and thick, slightly curved towards the point and terminating in a very short awn (Fig. 30). It is of a distinctly yellow colour, this alone being a ready means of identification.

FIG. 30.—Seed of Crested Dog's-tail magnified.

Crested dog's-tail is a native of dry, chalky, or stony fields, occurring both in pastures and meadows. On such soils it is of considerable value, particularly as food for sheep. For cattle, however, the leaves lie rather too closely on the ground to allow of their cropping them off very closely. For the same reason, in rich moist soils the plant occupies too much space in proportion to its produce. Another disadvantage of this

Fig. 81.—*1*, Meadow Fescue. *2*, Hard Fescue.

grass is that the stem becomes wiry very early in its growth, so that stock refuse it, and consequently it is almost always able to ripen its seed and therefore continually increases in proportion to other plants.

FIG. 32.—Seed of Meadow Fescue magnified.

Meadow Fescue (*Festuca pratensis*).—This is perhaps one of the most important grasses commonly grown. The seed-head is branching, and the spikelets are long, and frequently contain 6 or 8 florets (Fig. 31, No. 1). The base of the stem at the ground level is of a bright red colour, and the blades of the leaf are ribbed on the face and shining and smooth on the back, tapering gradually for almost the whole of their length. This tapering is much more gradual than in the case of crested dog's-tail, and the texture of the leaf is not so stiff as in that grass. The blade is somewhat keeled and slightly V-shaped in section. The seed is about the same size as cocksfoot, sometimes rather larger, but is less keeled in shape, and is usually less sharp-pointed at the top of the seed. If it is examined closely five veins will be found at the back; but these are usually not very distinct except near the point. Attached to the base of the seed, lying along its face, is a small stalk or pedicel, which in the complete spikelet serves to support the next seed. This is an important means of distinguishing the meadow fescue seed from that of other plants. It is cylindrical, of about the same thickness throughout, and usually stands out somewhat from the face of the seed (Fig. 32). The seed is very commonly adulterated with that of perennial rye grass (*Lolium perenne*), which will be

FIG. 33.—Seed of Soft Brome magnified.

described later on, and the soft brome (*Bromus mollis*) (Fig. 33), and the rye brome grass (*Bromus secalinus*), which are both awned.

Meadow fescue grows best in moist land of a medium texture. On dry soils it only gives moderate produce, but except in very sandy land it is still a useful plant to grow. It produces a large amount of leaf of very high feeding value, and stock will readily eat even the stems. It produces a very close bottom growth or sole in grass land, and is therefore perhaps better for grazing than for cutting to hay.

Tall Fescue (*Festuca elatior*).—By many botanists this is considered a variety of the meadow fescue, and it is chiefly distinguished from that plant by its larger size and stronger, coarser habit of growth. It forms large tufts in pastures, from which tall, coarse stems rise, carrying a large, spreading seed-head like that of meadow fescue. The stem is of a rich red colour at the base, and the leaves are dark green in colour, are rough and coarse, markedly ribbed on the face, glossy and smooth on the back, and tapering rapidly all the way from the base to the tip. The seed is also very similar to that of meadow fescue, but is furnished with a short awn, and is usually slightly split or forked at the point.

Tall fescue will succeed in rather moist soils, particularly on stiff clays. Owing to its coarse appearance farmers often object to its presence in grass land; but it is a most valuable grass, and stock eat it very readily and thrive well upon it.

Sheep's Fescue (*Festuca ovina*).—This is a very small plant which grows in close, compact tufts. The seed-head is small and spreading, the spikelets being sharp-pointed and sometimes slightly awned. The stems are very fine and the leaves are narrow and bristle-like, being closely folded down the mid-rib. The sheath is tufted or split for the whole of its length, this serving as a distinction between the sheep's fescue and the various-leaved and creeping fescues. The seed is small and sharp-pointed, slightly roughened at the edges of its coverings and towards the top. The soil which suits sheep's fescue best is of a light, dry character, as, for instance, on chalk downs or sandy or rocky upland pastures. As its name implies, it is a useful food for sheep, but its

seeds are long and narrow, with a little short hair on the back, and a rough awn not more than half the length of the seed itself, which springs from the back of the seed, not from the point. The top of the seed is divided and slightly flattened.

This plant occurs only on dry soils, particularly on those of the chalk and some of the oolitic limestones. It is of very little value, as stock will usually refuse to eat it if other food is obtainable. On very dry soils, particularly if shallow, it is perhaps sometimes useful, though it is not ever a plant to be encouraged in grass land.

Barren Brome (*Bromus sterilis*).—This plant is distinguished by its very fine wiry stem and wide-spreading seed-head. The spikelets also are long and narrow, and furnished with long, fine awns. The leaves are short, and covered with short, stiff hair. The seeds are long and narrow, with the awn about twice their own length, and the top of the seed is distinctly divided into two sharp prominences.

The barren brome occurs chiefly on waste land, and is an indication of poverty or exhaustion of the soil. It is only found in grass land on the poorest sands and dry, rocky soils. It is of no value for feeding purposes, and is therefore not a plant for cultivation.

The Rye Brome (*Bromus secalinus*).—This is a plant of rather large size, which has a spreading seed-head with rather large, flattened spikelets. The leaves of the plant are rather similar to those of the upright brome. The seed is large and broad, and carries an awn about its own length. It is sometimes a troublesome weed on arable land, particularly occurring in corn crops, but is not usually to be found in permanent grass land.

The Soft Brome (*Bromus mollis*).—This is rather similar to the last-mentioned plant, but is smaller in its growth, and softer and more downy in its general character. The spikelets are soft and covered closely with hair, and are distinctly awned (Fig. 34, No. 1). The whole plant, both stem and leaves, is covered with rather coarse hair, and the edges of the leaf are downwards rough, that is, feel rough when the fingers are drawn down the leaf from the point towards the base. The seed is rather flat and carries an awn which rises from the mid-rib of the pale, a short distance from the point.

FIG. 84.—1, Soft Brome. 2, Yellow Oat Grass. 3, Creeping Wheat Grass. 4, Perennial Rye Grass.

The soft brome, though occurring commonly under all conditions, is a sign of poverty or exhaustion if present in large quantity. Its seed is, however, a common adulterant or impurity in those of other grasses, and it is therefore frequently introduced unintentionally into pastures, both temporary and permanent. As a feeding stuff it is of little or no value, as stock will never eat it if other food is obtainable.

Wild Oat (*Avena fatua*).—This plant is rather similar to the cultivated oat in its general appearance, but is smaller and produces less leaf in proportion to its size. The seed-head is wide and spreading, the glumes or outer cover of the spikelets being very large, and containing two or three seeds. The seeds are like oats of thin, coarse quality, and they are furnished with a long, twisted, and bent awn, about twice the length of the seed. There is a good deal of long, conspicuous hair about the base of the seed. This plant grows in all kinds of soil, and is a common arable weed, but is not able to hold its own in competition with other grasses, so that it seldom, if ever, occurs in pastures. Stock seem to relish the plant, but owing to its small bulk it is not worth cultivating.

Downy Oat Grass (*Avena pubescens*).—The seed-head of this plant is finer and more feathery in appearance than that of the wild oat, the spikelets being much smaller, and the whole plant, leaf and stem, is covered with close hairing, from which its common name is derived. The blade of the leaf is not ribbed, but has two median lines similar to those described as occurring on the leaves of the meadow grasses. The seeds are rather like those of the wild oat, but are much smaller.

The downy oat grass occurs commonly in dry, upland pastures, particularly on chalk or limestone soils. Stock do not care for the plant, and will refuse it if possible. It is therefore not worth cultivating.

Yellow Oat Grass (*Avena flavescens*).—This is a smaller plant than the last two mentioned, and grows in a very erect manner. The seed-head is branching, and has a stiff, bristling appearance (Fig. 34, No. 2). It is readily recognised by its light green colour in the early stages of growth, and its golden or yellow colour as the seed matures, from which the name "yellow" or "golden oat grass" is derived. Both

the blades of the leaves and the sheaths are covered with fine, soft hair, and are usually of a light yellowish green colour. The seed is brownish-yellow, having a peculiar membranous appearance, owing to the thin texture of the seed covering. It is divided at the point, and carries a fine, twisted, and bent awn. The pedicel or stalk of the seed is covered with rather long, fine hair, springing out evenly from its sides. It is frequently adulterated with the seed of the wavy hair grass, and may be distinguished from it by the fact that in the wavy hair grass seed there is hairing round the base of the seed itself, and a tuft of hair springing out on each side of the base of the stalk, but not extending up its whole length. The seed usually has a very low germinating power.

The yellow oat grass grows commonly on dry soils, particularly if they contain a good deal of lime. It also succeeds well on sandy soils, on which it is one of the most important plants occurring in grass land. It forms a large number of stems, but in spite of this cattle eat it readily, and apparently do not object to the hair which covers it as much as they do in the case of most hairy grasses. It is perhaps more valuable for sheep than for cattle, but it is also a good grass for making into hay.

Meadow Barley Grass (*Hordeum pratense*).—The seed-head of this plant is similar to that of four or six-rowed barley, but is much smaller, the spikelets being less perfectly developed. It produces narrow hairy leaves, rather rough in texture, but does not generally produce any large quantity of fodder. On rich, moist soils it does better, and is readily eaten by all kinds of stock; but in dry soils, where it is more frequently found, its value is very slight, and the stiffness and coarseness of the awns make it an injurious food for live stock, especially if given to them as hay. Its chief use is for feeding early in the year, when quite soft and succulent, and this is particularly the case because its growth takes place early in the season.

Creeping Wheat Grass (*Triticum repens*), also called "couch," "cooch," "twitch," "wicks," "quicks," and a number of other similar names. This plant has a markedly creeping habit of growth, the greater part of the plant usually being underground. It spreads by means of stolons

through the surface soil, sending out roots at the nodes, and occasionally sending a shoot up into the air. The proportion of leaf is very small. The seed-head consists of a central stem, with spikelets placed alternately upon it, the side of the spikelet being next the central stem (Fig. 34, No. 3). The leaf is usually dark in colour, very slightly haired, particularly about the junction of the sheath and blade, and with a very short ligule, which, if examined with a magnifying glass, is seen to be furnished with a row of very short, fine teeth at the edge.

The creeping wheat grass occurs commonly in all parts of the country and in all kinds of soil, and forms one of the most troublesome arable weeds. It is on light, free-working soils that it extends most rapidly through the surface soil, doing great harm by exhausting the soil and tending to choke out the cultivated crops. It does not occur in permanent grass land, as it is usually kept in check by the ordinary grasses. It is most difficult to get rid of, as the creeping stems, if broken, begin to spread again at once, and each knot is capable of forming a point of growth.

Bearded Wheat Grass or Dog Wheat (*Triticum caninum*).—This plant is very similar to the creeping wheat grass, but occurs in rather more sheltered situations, being frequently found in woods. The lower surface of the blade is much rougher, and if the blade be held up to the light and examined with a lens, a number of white lines will be seen running all down the leaf. The seed carries a long awn, which serves as a convenient distinction between the two plants. This plant has been recommended for cultivation, but it is of low value, and, except in plantations, is certainly not worth sowing.

Heath False Brome (*Brachypodium pinnatum*).—This is not usually an important grass, but occurs commonly in pastures of the limestone formations. It is a tall plant, having a seed-head rather like that of the creeping wheat grass, but longer, with greater space between the spikelets, and the spikelets themselves longer and narrower. The leaves are very slightly ribbed, and both the blade and sheath are covered with hair. In feeding value this plant does not stand particularly high, and in most situations might be replaced by other grasses with advantage.

Perennial Rye Grass (*Lolium perenne*).—The seed-head of this plant consists of a central stem or axis, with the spikelets set alternately at either side of it, somewhat like the creeping wheat grass; but the spikelets are set with their edges turned towards the central stem instead of their sides (*Fig.* 34, *No.* 4). *The base of the stem is of a red* colour, and the leaves are dark green, distinctly ribbed on the upper surface, and shining and smooth on the back, having very much the same appearance as the blades of meadow fescue. They may be distinguished, however, by

FIG. 35.—Seed of Perennial Rye Grass magnified.

FIG. 36.—Seed of Dock magnified.

FIG. 37.—Seed of Buttercup magnified.

being more markedly keeled, and by being of the same width for about two-thirds of their length, after which they taper rapidly to the point.

The seed is also very like that of meadow fescue, and is distinguished from it by the pedicel or stalk, which in the rye grass is flattened and rather wider at the top than at the base. It also rests closely against the seed (Fig. 35). The weight per bushel of rye-grass seed is usually 24 to 28 lbs.; if much lighter than this it probably contains some impurity. The most common impurities are the seeds of Yorkshire fog, soft brome, and rib grass (*Plantago lanceolata*). Other kinds of bromes frequently occur, and the seeds of the dock (*Rumex obtusifolius*) (Fig. 36), the sorrel, and varieties of the buttercup (*Ranunculus*) (Fig. 37).

Perennial rye grass grows well under almost all conditions,

succeeding best, however, in medium or heavy land, particularly if moist in character. It is then a true perennial: but in dry soils or dry climates it gradually dies out or maintains its position by seeding itself. Different varieties of the plant also vary very greatly in their value, some, as for instance what is sold under the name of annual rye grass, only producing one crop, and being therefore unfitted for permanent pastures. It is a valuable plant, growing thick and producing good bottom in grass land, while its feeding value is considerable. A good deal of discussion has taken place at various times with regard to the value of the plant, and it has been shown that it frequently occurs in large quantities in first rate pastures. It is probable, however, that where soil and climate will allow of the growth of such grasses as meadow foxtail, timothy, meadow fescue, etc., rye grass should not be sown in large quantities. It has a great tendency to run to seed, and by so doing to exhaust its strength, after which it is likely to die out or at any rate diminish in produce.

Italian Rye Grass (*Lolium italicum*).—This plant is an annual or biennial, and so is only suitable for growth in temporary pastures. It is strong and rank in its habit, forming large conspicuous tufts, and is very similar to perennial rye grass, but on a larger scale. The seed-head is similar, except for the fact that the spikelets are awned; the stem has the same red colour at the base, and the leaf is ribbed on the upper side, and shining and smooth on the lower. The keel of the blade, however, is less marked than in perennial rye grass, and the leaf is flatter and broader. Before it opens, the blade is rolled in the sheath, making the stem approximately round, whereas in perennial rye grass the leaves are folded in the sheath and the stem is more flattened. The colour of the plant is rather lighter. The seed is like that of perennial rye grass, but usually rather lighter, and furnished with an awn nearly as long as the seed itself. The common impurities occurring in Italian rye-grass seed are the same as those in that of perennial rye grass, viz. Yorkshire fog, soft brome, rib grass, dock, sorrel, and the buttercup. There is also frequently an admixture of perennial rye-grass seed.

Italian rye grass grows well on almost all soils, preferring,

however, rather moist, warm loams. It is specially noted for its rapidity of growth and for producing a large quantity of food for stock early in the spring. It is also particularly suited for irrigation and is one of the most common crops for use on sewage farms (see page 126). Though it is commonly a biennial in this country, if it is kept constantly grazed or is always cut very early in its growth it will last longer than if it is allowed to form seed. Owing to its tufted habit of growth it is commonly sown with other plants, often with clover or hop trefoil, but then it often happens that the rye grass ripens before they are ready and therefore becomes woody and of small value before it is made into hay. For grazing, however, there is not the same disadvantage, and a mixed crop will then usually produce more fodder than Italian rye grass alone.

CHAPTER XXVIII

THE LEGUMINOUS AND MISCELLANEOUS PLANTS FOUND IN GRASS LAND

Broad Red Clover (*Trifolium pratense*).—This is a plant, annual or biennial in its growth, which is largely used for temporary leys. The flowers vary in colour from almost purple to pale pink, and are massed together to form oval or rounded flower-heads. The stems are of a green colour throughout and carry very little hair, except on the leaf-stalks, and even there chiefly in the young plant. The stems are usually hollow, but not invariably. The leaves, like those of other members of the genus *Trifolium*, are composed of three leaflets, which are large and broad, haired all over in the younger stages of the plant's growth, but later only slightly haired at the edges, with a clear white marking on the centre of each leaflet. The stipules, or appendages at the base of the leaf-stalk, are long-pointed and of a membranous character, green-veined, and with long, conspicuous hairs towards the point. The root is thick and less fibrous than that of any of the clovers. The habit of growth of the plant generally is rather loose and unbranched. The seed is rounded and oblong, slightly flattened, and varies in colour from purple or red to yellow (Fig. 38). The proportion of yellow seeds, however, should not be large, as they rarely germinate so well as the darker ones. In any case, except in German or Russian seed, a brownish shade of colour is to be avoided, for either the seed has been harvested in bad weather or it is old seed, of a previous season's

FIG. 38.—Seed of Broad Red Clover magnified.

growth. In either case its germinating power is likely to be low. Common impurities occurring in the seed are the seeds of various kinds of crane's-bill, as, for instance, the jagged-leaved crane's-bill (*Geranium dissectum*), which are oval in shape and smooth; the seed of the dock, which is angular and three-sided, pointed at each end, and smooth and glossy, varying in colour from yellowish to almost black; the seed of rib grass, of the red and white campion (*Lychnis diurna* and *L. vespitina*), and of the knap weed (*Centaurea nigra*). It is also often adulterated with the seed of hop trefoil, from which it may be distinguished by the absence of the projecting tip of the radicle visible in the trefoil seed.

There are *many* kinds of *broad red clover used in this* country, which vary to some extent in their characters. Probably the best is the English clover, which is hardy and gives a large produce. The seed, if well harvested, is usually of a reddish-purple colour. The Canadian has been used a good deal of late years, and also grows remarkably well, having the habit of making little progress till later than the English clover, but growing very fast when the warm weather fairly begins. The seed is usually of a very bluish-purple colour, individual seeds being either purple or yellow, comparatively little red seed occurring. Clover seed is also imported from the United States, producing plants rather more hairy than those of the English clover, but apparently not quite so hardy. French clover is also grown in this country, but if brought from the south of France it is very delicate, though the seed produced in the north will succeed quite well in our climate. German and Russian clover seeds are also imported, and though they frequently grow fairly well, are usually of a brownish colour. One kind, Silesian, is intermediate in its characters between the broad-ribbed clover and the perennial red, which will be next described, being more lasting than the true broad red and later in flowering.

Perennial Red Clover (*Trifolium pratense perenne*).—This plant is usually called cow grass by seedsmen and farmers, though there is some confusion about the term, which has been applied by botanists to another plant. Perennial red clover is very similar to broad red clover, and individual specimens are not always distinguishable. In its habit of

growth it is usually more branched and not quite so tall as broad red clover; the root is more fibrous, and the stem solid and more hairy. It also frequently has a red line running its entire length. The flowers are darker in colour and appear some weeks later in the year than those of broad red clover. The leaflets are narrow, of a darker colour, the white marking being less defined or sometimes absent. They are also more thickly haired. The stipules are longer and narrower, though otherwise similar to those of broad red clover. The seed is like that of broad red clover, and cannot be accurately distinguished. It should, therefore, be bought only from a reliable seedsman, as the difference in price offers every inducement to a fraudulent dealer to substitute broad red clover seed for that of cow grass. Cow grass gives a rather heavier cutting than broad red clover, and is therefore used in rotations in some districts, particularly in Berkshire and Hampshire. It gives little or no second crop, however, so that probably broad red clover gives the largest produce in the year. Cow grass is hardier than broad red clover and is rather less liable to clover sickness. It may therefore often be grown where broad red clover would fail. Cow grass is commonly used for sowing in mixtures of seeds for permanent pastures, but it is not usually found in large quantity in grass land.

Zig-zag Clover (*Trifolium medium*), also called marl clover or marl grass, and sometimes cow grass.—The general appearance of this plant is very similar to that of perennial red clover, but it is smaller and distinctly zig-zag in the stem, which bends at each knot; the flower-head is rather oblong and less compact than that of perennial red clover, and the leaves are narrower, and are not marked with white. The root gives us, however, the most distinctive point of difference, for it is creeping. The seed is rarely sown intentionally, the plant occurs naturally in many old pastures, where, mixed with other plants, it is very useful, being a true perennial. It is most common on rather cold clays and in soils containing a good deal of organic matter, attaining its largest development under the latter conditions. In its produce it is smaller than perennial or broad red clover.

White Clover (*Trifolium repens*) or Dutch clover. This

is a perennial plant, with a large *tap-root*, from the top of which a number of creeping stems spring, which, resting on the surface of the ground, send up leaves into the air and rootlets into the soil. The plant is thus able to withstand all conditions of weather, in times of drought drawing moisture from the subsoil by means of its main root, while in very wet seasons the main root is of little use to it, and it feeds by means of its surface roots. The leaves are *composed* of three leaflets, which are rather broad and distinctly marked with white in the centre. The leaf-stalks are rather *long and ribbed; the flower-heads are round*, consisting of white flowers, which, however, have a distinctly brownish tint. The flower-stems are sufficiently long to carry the flowers above the level of the leaves. The seed is much smaller than that of red clover, more irregular in shape, and of a yellowish or brownish colour (Fig. 39). Good samples are usually of a bright yellow, but if injured by the weather in the process of harvesting, or if they have been kept for any length of time, they are darker. One of the commonest impurities is the seed of the sheep sorrel (*Rumex acetosella*), a small seed, similar in shape and colour to that of the dock, but of almost exactly the same size as white clover seed. It is therefore difficult to separate it from the clover seed, but it is easily distinguished by its glossy, shining surface, which can be readily seen amongst the comparatively dull seeds of the clover. The seeds of knot grass (*Polygonum aviculare*) and other members of the genus *Polygonum* also occur, being of about the same size as white clover seed, but pear-shaped and rather flattened. They are also usually of a grayish-brown colour, quite different from that of the clover. The seed of timothy and that of rib grass also frequently occur.

FIG. 39.—Seed of White Clover magnified.

White clover is chiefly useful for grazing purposes, its creeping habit of growth making it unsuitable for cutting to hay. It is particularly good for sheep when mixed with other plants; if used by itself the sheep must be put on it with great care at first. In very dry, poor soils its growth is always very small, but by manuring, or liming in some cases, it may be so much encouraged as to cause a common belief that liming the land produces the clover.

White clover grows commonly in grass land by the road-sides, but the cultivated variety, the seed of which is usually sold by seedsmen, is much larger and stronger in its growth than that occurring naturally in waste places.

Alsike (*Trifolium hybridum*) or Swedish clover.—The appearance of this plant is intermediate between that of red clover and white clover, and it has been considered by some botanists to be a cross between the two, hence its systematic name. The stem rests on the ground for a short distance and then rises into the air. It is but little branched, is smooth and hollow: the flowers are of a pinkish-white colour, never having the brown tint observed in white clover until withering takes place. The leaflets are like those of white clover, but rather larger, and rather sharper-pointed. The stipules or appendages at the base of the leaf-stalk are very conspicuous, and wrap entirely round the main stem, and are not quite so sharp-pointed as in red clover. The seed is like that of white clover in size and shape, but is of a dark green colour. If almost black, as sometimes occurs, the seed has probably been badly harvested or has been kept too long. It is sometimes artificially coloured, and this may be detected by moistening the seed and rubbing it between the folds of a white cloth, when, if it has been artificially coloured, the cloth will be stained. The common impurities occurring in the seed are similar to those mentioned in the case of white clover, with the addition of the seed of the clover dodder (*Cuscuta trifolii*), a parasitic plant which is sometimes very injurious to clover crops. This seed is rather smaller than that of alsike, rounded in shape, and of a grayish-brown colour.

Alsike is a very hardy plant, growing sometimes at great elevations, and having great power of resisting cold or wet. It does not, however, do well in times of drought, yielding only a very small produce. It is much less liable to clover sickness than other kinds of clover, and is consequently often employed where other clovers would fail. It will succeed well on irrigated land, and is, in fact, the only clover well suited for such a situation. It has one disadvantage owing to its habit of growth, namely, that on damp soils, where the crop grows thick, it is very liable to rot at the bottom, owing to the fact that the stem lies flat on the

surface of the ground for some little distance before rising into the air. It must, therefore, be cut rather early in moist soils and seasons.

Suckling Clover (*Trifolium minus*) or yellow clover.—This is an annual plant occurring naturally on many soils, maintaining its position by constantly seeding itself. It is very small, having a slender stem, small leaflets, and small heads of yellow flowers very similar to those of hop trefoil, but which, on examination with a glass, show the calyx tubes free from hair. When the flower withers the petals still remain on the plant, thus forming another distinction between the suckling clover and hop trefoil. The seed is about the same size as that of white clover, but is round in shape, and shining and glossy.

Suckling clover grows naturally on dry, rocky soils, particularly those containing a good deal of lime, and on such land is very useful, as other larger plants will not generally succeed. It is best used as a pasture plant, as it often keeps growing throughout the season; but if cut to hay it yields no second crop.

Hop Clover (*Trifolium procumbens*).—This must be distinguished from the hop trefoil (*Medicago lupulina*), which is also sometimes called "hop clover." The true hop clover is a larger plant than the suckling clover, more spreading in its growth, with a larger, looser flower-head, the flowers being of a lighter yellow, but also having a calyx free from hair. When the flower withers the petals remain adhering to the plant, and the supposed resemblance of the flower-heads at this stage to hops gives the plant the name "hop clover." Like the preceding clover, it is useful in very dry pastures, particularly those resting on limestone, where it grows well, but it is seldom sown intentionally.

Bird's-foot Trefoil (*Lotus corniculatus*).—This plant occurs naturally in most pastures in the country, and is distinguished by its flower-head, which consists of usually less than half a dozen yellow flowers, frequently tinged with red and sometimes green. They form a crown about the top of the flower-stalk, sticking out from it at right angles. When the flowering is over, long conspicuous seed-pods are produced, and the supposed resemblance of these to the foot of a bird gives the common name to the plant. The

stem is angular and free from hair, and the root is spindle-shaped and branches very little, and the main stem which rises from it is very short, but produces a number of branches, some of which ascend directly into the air, while others rest on the ground for some little distance. These stems, however, never root into the soil. The leaves are small and are composed of fine leaflets, of which the lowest pair is very small. The leaflets are dark green on the upper side, and a bluish-green colour below. The seed is rounded and of a brown colour, being a little smaller than turnip seed. The seed of another species of this genus is also sold in the market, the marsh bird's-foot trefoil (*Lotus uliginosus*), and is useful, as its name implies, for growth in wet places. Its seed is a good deal smaller than that of the common bird's-foot trefoil, and is of a greenish colour, though with an admixture of yellow seeds. Other varieties are also sometimes met with that are not of much importance.

Bird's-foot trefoil is very useful in permanent grass lands as making bottom growth, either for mowing or depasturing. It is, however, never sown by itself, as the produce is not sufficiently great; and it is not often sown in mixtures for permanent grass, as it occurs naturally in moist soils. It specially suits soils containing a good deal of lime, but it does not yield a large produce if the climate be dry. It is a very hardy plant, being often found growing naturally at great elevations, and will yield satisfactory produce on very poor land. When it is used in a green state it should be cut or fed a little before flowering time, for it is said that the colouring matter of the flowers is bitter to the taste, and is not relished by stock. For haymaking, however, it should be in full flower, as it then has its maximum feeding value.

Meadow Vetchling (*Lathyrus pratensis*) or everlasting pea.—The general appearance of this plant is rather similar to that of the cultivated vetch; but the whole plant is smaller and finer in its growth, and the flowers are yellow and grow several together in a head. The leaves are narrower, but like those of the vetch in terminating in tendrils. The plant is perennial, flowering usually in June; but it lasts well into the autumn, yielding a moderate produce. It is not grown by itself, as it does not yield a

sufficient crop for the purpose; but it is very useful grown with other plants, as its creeping habit of growth enables it to fill up the spaces between the other plants, and thicken the crop considerably. It grows naturally on dry, calcareous soils, for, owing to its deep root, it is able to withstand drought.

Before considering the miscellaneous plants growing in grass land a word must be said with regard to two parasitic plants injurious to clovers and other leguminous crops. The clover dodder (*Cuscuta trifolii*) forms a tangled growth of small stems or tendrils, wrapping closely round the stems and leaves of the clover, and sending suckers into the tissues of the clover wherever they touch it. The dodder, which sends no roots into the soil and has no leaves, thus lives entirely upon the clover plant, and so gradually destroys it. The dodder forms patches surrounding every centre from which growth commences, and thus rapidly extends until a great part of the crop may be destroyed. Though at first green and not very noticeable, the dodder afterwards becomes of a yellow or brownish colour. When the attack has commenced the affected patches should be cut as closely as possible, and the clover and dodder carried away and, if possible, destroyed. The surface soil should also be dug over, so as to prevent further growth of dodder, and great care must be taken to prevent seed being formed by the parasite. In no case should the crop affected by dodder be allowed to stand for the production of seed.

The second parasite to be mentioned is broom rape (*Orobanche minor*), a plant which sends up a spike of flowers of a brownish-purple colour, growing apparently separate from the clover plant. If the roots of the plant are examined, however, it will be found that the broom rape has attached itself to the roots of the clover, though not very firmly. The injury done by broom rape is not usually so great as that done by dodder.

Passing on to the miscellaneous plants occurring in grass land, one of the most important is—

Rib Grass (*Plantago lanceolata*) or narrow-leaved plantain. The flower-head of this plant is a small, compact spike, black in colour except at flowering time, when it puts out a number of stamens of a purplish colour. The flower-

stalk is ribbed, and the leaves, which are rather narrow, are also ribbed conspicuously in the direction of their length. The seed is brownish in colour, rather long and narrow, and with a groove or channel running down one side, somewhat resembling a grain of wheat in shape, though a good deal longer in proportion.

Rib grass grows freely on light soils, and does well in dry climates. It also succeeds well in high, exposed situations. It is commonly sown in permanent mixtures; but it is not a very good plant for the purpose under most conditions, for, owing to the fact that the leaves lie almost flat on the ground, stock are unable to graze the plant closely, and it occupies a large amount of space compared with the produce it yields. For meadows it is less objectionable, as, growing amongst tall plants, the leaves are drawn upwards, and do not occupy so much of the surface. It has this disadvantage, however, for making into hay, that it takes a long time to dry, and becomes of a black colour in drying, to some extent injuring the appearance of the hay when made. Its feeding value is, however, high, and its presence in a sample of hay is no disadvantage for feeding purposes.

Burnet (*Poterium sanguisorba*).—This plant is common in pastures, particularly on soils containing a large quantity of organic matter and some lime. It also is commonly found on limestone land. In general appearance the immature plant is sometimes mistaken for sainfoin; but though the leaves consist of a number of leaflets arranged in the same way as those of sainfoin, the leaflets are of a lighter colour, much broader in proportion to their length, and are toothed at the margin, while the leaflets of sainfoin are entire. The flower-head of burnet is a small, compact spike, usually green or black in colour, except just at flowering time, rather inconspicuous, and altogether different from that of sainfoin. The seed, which is a common adulterant of rough sainfoin, is of a light brownish tint, roughly four-sided and pointed at each end, and covered on all sides with small, jagged points, quite different from the even network covering the husk of sainfoin. Burnet has been used to some extent as a forage crop, but its growth has never been general. It is, however, eaten readily by sheep, and apparently with good results.

Yarrow (*Achillea millefolia*) or milfoil. On light, dry soils, particularly those containing lime, this plant is found commonly. It is deep-rooted, and spreads by stolons below the surface of the soil. The flower-head, which consists of a number of flowers, is white or pinkish, and appears usually about the end of June or later. The leaves are of a very dark green colour, long and narrow, and very finely divided or cut, thus giving the name of milfoil to the plant. The seed is small and rather flattened, and of a silvery colour. It very often has only low germinating power, and is expensive. In consequence of this yarrow is often omitted in mixtures for permanent grass land; but where sheep are kept in large numbers it is a useful plant, for these animals can graze the plant well in spite of its habit of growing close to the ground. It has an aromatic smell, which apparently is liked by stock, and it is useful, therefore, as a flavouring matter mixed with other kinds of fodder.

Sheep's Parsley (*Petroselinum sativum*).—This plant resembles the ordinary cultivated parsley very closely, but has not quite such a finely-divided and curled leaf as that variety. It is not quite permanent, and should not therefore be sown in large quantities in permanent mixtures; but it is useful as giving a flavour to other plants with which it may be growing, and sheep are particularly fond of it.

CHAPTER XXIX

TEMPORARY AND PERMANENT GRASS LAND

Temporary Grass Land.—It has been stated in the chapter dealing with rotation of crops that mixtures of grasses and clovers are usually grown in some part of the rotation, and this is particularly convenient as it increases the amount of grass land available either for mowing or depasturing. When the crop has to remain down for one year, less care is needed in the selection of plants to suit the conditions, but for longer periods great care is required in choosing the kind of plant that is adapted to the soil, climate, and situation, and to sow the seed in the quantity necessary to give the best result. Thus, for a one-year ley quick-growing, bulky plants are chiefly employed, so that a full yield of forage may be obtained, but for leys for longer periods, particularly for three years or more, plants maturing more slowly may be employed, in order to maintain the pasture in a thick and free-growing condition until the time comes for breaking it up. Besides choosing plants suited to the conditions of soil and climate, it is also necessary to think of the purpose for which the seed is sown, for if a crop has to be mown, upright plants are required. If, on the other hand, the crop has to be grazed, plants having a creeping habit of growth may be employed to a great extent to fill up the spaces between the more upright plants. The following table gives a number of examples of mixtures employed in various parts of the country for leys for one year:—

Table XLVI.

Mixtures of Grass and Clover Seeds for One Year Leys.

In Lbs. per Acre.

	1.	2.	3.	4.	5.	6.	7.
White clover	5½	6	6	5	2	...	6
Broad red clover	2	6	4	5	10	11	9
Alsike	2	...	2	...	...	...	...
Cow grass	...	...	2	5	...	...	...
Italian rye grass	4	...	...	2	8	4	...
Hop trefoil	5½	10	...	...	...	...	3
Cocksfoot	1	...	...	...	...	...	...
Timothy	1	...	...	...	...	...	...
Rib grass	1½	1	...	...	...	...	...
Sheep's parsley	1½	1	...	...	...	...	...

Nos. 1 and 2 are examples from the Wolds of the East Riding of Yorkshire, both being for grazing purposes; No. 1 where the seeds are not to be followed by wheat, No. 2 where wheat is to be the next crop. It will be observed that where wheat is to follow a large proportion of clover is employed, whereas where wheat is not next in the rotation grasses are sown to a considerable extent. Nos. 3 and 4 are from the North Riding of Yorkshire; No 3 for grazing purposes for sheep, No. 4 for mowing. Nos. 5 and 6 are from Norfolk, both for mowing purposes, and No. 7 is from the Midlands, also for mowing. It may be noticed that a larger proportion of hop trefoil is usually used on light soils, though for one-year leys not very much difference is usually made between light and heavy soils. The rib grass and sheep's parsley in Nos. 1 and 2 are not commonly used in any district, but might certainly be employed with better advantage for grazing for sheep than in any other way.

Leys for two or three years usually contain a larger proportion of grass seeds and less clover. Perennial rye grass, which is rarely, if ever, sown in a one-year ley, is usually introduced to a certain extent in those of longer

duration. The following table gives examples of mixtures for two or three-years leys:—

Table XLVII.

Mixtures of Grass and Clover Seeds for Two or Three-Years Leys.

In Lbs. per Acre.

	1.	2.
White clover	2	3
Broad red clover	5	3
Cow grass	5	2
Alsike	2	2
Hop trefoil	2	3
Italian rye grass	2	1
Perennial rye grass	4	2
Cocksfoot	...	2
Timothy	...	2
Rib grass	...	1
Sheep's parsley	...	1

No. 1 is from the Midlands and No. 2 from the East Riding of Yorkshire, both being for grazing purposes. It will be noticed, particularly in the second example, that the more permanent grasses, cocksfoot and timothy, are sown in considerable quantity, while in No. 1 perennial rye grass is chiefly employed.

Rotation mixtures of seeds are almost always sown with the corn crop, barley being perhaps the best for this purpose. The usual time of sowing is in the spring, when the corn crop shows the line of drill distinctly. The seeds are sown broadcast or with the drill, the latter being preferable, as the seed is better covered and more evenly sown than by broadcasting. Covering the seed is of considerable importance, as seeds merely scattered on the surface germinate very badly even if not eaten by birds. The following table gives the results of experiments on the germination of grass and other seeds sown at various depths:—

Table XLVIII.

Number of Plants produced per cent of Seeds sown at Various Depths.[1]

	Italian Rye Grass.	Perennial Rye Grass.	Timothy.	Red Clover
Surface	13·25	14·7	13·5	7·5
¼ inch	59·6	60·6	48·5	65·5
½ ,, ...	62·2	61·0	54·5	66·5
¾ ,, ...	63·3	62·0	50·0	59·9
1 ,, ...	56·0	61·0	44·2	44·4
1½ ,, ...	47·5	51·0	23·2	29·6

If a drill is used the small seeds should be sown across the rows of the corn, as by that means a more regular sowing is possible. A light harrow usually follows the drill, or sometimes a light wooden roller, the object being to cover the seed lightly without compressing the soil too much.

When the corn crop is cleared, the seeds are often rather weak and thin, but in damp seasons they grow very strongly, and will usually afford food for sheep or for stock in the autumn. Great care must be taken, however, particularly in the case of the clovers, not to graze too late in the autumn, and not to allow any stock upon the seeds in time of frost. At such a time "a sheep has five mouths," as it is expressed, for it destroys as much of the plant by trampling on it when the frost is on the leaves as it does by eating. Every leaf bruised withers and turns black almost immediately. Sometimes a light dressing of artificial manure is given to seeds in the spring, particularly when the proportion of grass seeds is high compared with that of the clover. Nitrate of soda is often used in dressings varying from half a hundredweight to a hundredweight per acre. Where it is used, however, great care is needed in feeding stock put on the crop, for it is very likely to make sheep or cattle scour badly. Where the crop is to be cut to hay it is not usually possible to get

[1] *Transactions of the Highland and Agricultural Society*, 5th series, vol. v.

much food for stock from it in the spring, but much will depend upon the season, and usually, for a short time at any rate, it may be fed off by ewes and lambs or other stock. The process of haymaking will be described separately.

Permanent Grass Land.—The choice of the kinds of seeds to be sown in laying down land to permanent grass, and the quantities of each to be employed, requires very careful consideration with reference to the character of the soil, the climate, and to some extent the purpose for which the grass is to be employed. The plants must also be chosen with reference to one another if the maximum produce is to be obtained. It has been estimated that in a good old pasture there are on the average about forty million plants to the acre, but it is not economically possible to sow sufficient seed to produce such a large number of plants at once, and the plan is generally adopted of sowing seed enough to produce from fifteen to eighteen million plants per acre, and to rely upon the natural thickening of perennial plants for the ultimate occupation of the soil. In laying down permanent grass land it is quite useless to sow the seed of any plant which is not well suited to the soil and climate, for if this is done, in the course of a few years the plants will become thin and weak, and will eventually die out. It is also necessary to sow as far as possible plants which will occupy the soil permanently, either truly perennial plants or those which have the habit of seeding themselves to a sufficient extent to be practically perennial. It is a common plan to mix with the seeds of the perennial plants a certain proportion of those of temporary grasses in order to obtain a large produce in the first few years. This is not, however, a good plan, for the temporary plants will for the first year or two occupy a good deal of space, and prevent the proper development of the permanent ones, and may indeed choke them out altogether. Then, when the temporary plants die, there is nothing to take their place, and weeds will find their way into the grass land and permanently injure its value. It is, therefore, better to sacrifice something in the produce of the first few years in order to obtain a better final result.

As to the purpose to which the crop is to be put, if the land is to be constantly mown, the plants should be chosen as far as possible to mature at the same time, so that they

can be cut when all are at approximately their maximum feeding value. For pasture, on the other hand, it is well to have a mixture of early grasses and late, in order that there may be a regular supply of fodder all through the year. Large-growing plants should also be mixed with smaller ones so as to provide a large top growth and a close bottom growth or sole, and in this way far heavier produce is obtained than where large grasses or small ones only are cultivated. Similarly, deep-rooted plants and shallow should be sown, so as to draw their nourishment from the whole depth of the soil, and not only from the surface layer. The admixture of clovers with grasses is also useful, partly because the former draw for the most part on different constituents of plant food from the latter, and partly because clover, by its exceptional power of obtaining nitrogen from the air, helps to supply that element to the grasses, which otherwise would have difficulty in obtaining it. It has been stated that the presence of about 20 per cent of clover in a pasture gives the best results.

A very common method of laying down permanent pasture is by using hay seeds, that is, seeds of grasses and other plants collected in hay lofts, or obtained by mowing the seed-heads left ungrazed in the pastures late in the summer or autumn. It is claimed by advocates of this system that by using hay seeds obtained in the same district where they are to be sown, the grasses naturally suitable to that district will be introduced into the new pasture. Against this view, however, there are several very forcible arguments. First, not only the grasses and useful plants native to the district will be introduced, but the weeds occurring in the old grass will be sown with the new. Secondly, if the hay seeds are obtained from a crop that has been cut to hay, it is probable that a great part of the seed will be immature, and will therefore germinate badly and produce weak plants; and thirdly, if the seeds are obtained by cutting pastures late in the season, the seeds will be those of the plants that have been refused by stock, that is, plants for the most part of very low feeding value. In some cases good results have been obtained by the use of hay seeds, but it is a risky experiment, and is very uncertain in its results.

In choosing a mixture of grass seeds it is well to observe the kinds of grasses occurring in the best pastures of the neighbourhood where the new pasture is to be made. This will give an idea of the kinds of plants most suited to the district. The following are examples of mixtures of seeds for permanent grass land under various conditions:—

TABLE XLIX.

Mixtures of Seeds for Permanent Grass Land, in lbs. per Acre.

	1.	2.	3.	4.	5.	6.
Foxtail	10	4	...	2	2	2
Cocksfoot	7	10	14	3	3	10
Timothy	3	3	3	2	4	2
Meadow fescue	6	3	2	3	4	4
Tall fescue	3	8	...	...	4	3
Various-leaved fescue	...	...	...	1	...	...
Hard fescue	1	1	4	...	...	...
Sheep's fescue	1	...	4	...	...	...
Sweet-scented vernal grass	...	...	...	...	1	...
Rough-stemmed meadow grass	1½	2	...	2	3	...
Crested dog's-tail	2	2	5	1	4	2
Fiorin	1½	2	...	...	...	...
Golden oat grass	...	...	1	...	...	...
Italian rye grass	...	...	...	6	5	...
Perennial rye grass	...	...	...	6	6	...
Cow grass	2*	2*	1	3	...	1
Alsike	1	1	1	5	2	3
White clover	1	1	1	5	2	3
Hop Trefoil	...	...	...	...	...	2
Yarrow	1	1	2	...	...	½
Rib grass	...	...	...	1	...	1
* Given as perennial red clover	1 lb.	...	...	...	...	...
Cow grass	1 lb.	...	...	...	...	...

Nos. 1 to 3 are mixtures recommended by the late Mr. Faunce De Laune, none of which contain any rye grass, either perennial or Italian. No. 1 is given as suitable for a good, medium soil; No. 2 for a wet soil, and No. 3 for

chalky land. It may be observed that the quantity of the various grasses is regulated according to their suitability for the different kinds of soil. For example, foxtail, which requires a good, rather retentive soil, is sown to the extent of 10 lbs. per acre in the first class, 4 lbs. in the second, and is omitted altogether from the third. Similarly, cocksfoot, which is liable to become too rank and strong in its growth on good land, is sown at the rate of 7 lbs. in the first, 10 lbs. in the second, and in the third, where there is little risk of its attaining very large size, 14 lbs. is sown. So with the other grasses, meadow fescue ranging from 6 lbs. per acre on a good, medium soil, down to 3 lbs. per acre in a wet soil, and 2 lbs. in chalky land. No. 4 is a mixture reported to have given good results in Cumberland, and No. 5 is from Shropshire, where it has been used on stiff soil, while No. 6 has been successfully employed in the West Riding of Yorkshire on strong land. Nos. 4 and 5 contain a considerable amount of rye grass, the chief advantage of which is in lowering the cost of the seed mixture, but, as already explained, it is a doubtful policy to include so large a proportion of a temporary plant such as Italian rye grass. Where rye grass is used, it takes the place chiefly of the more expensive grass seeds, though the proportion of all the permanent grasses must be reduced to some extent.

In preparing the land for sowing a permanent mixture of seeds, it is essential to make it rich in plant food and thoroughly clean. The actual method of obtaining these conditions will vary according to the soil and climate, but usually either a bare fallow is given in the previous year, or a crop of turnips or other roots is taken and carefully cultivated and cleaned all through its growth. Some authorities recommend taking two consecutive crops of roots, so as to clean the land more thoroughly and get it into better condition. On the other hand, it has been occasionally recommended to sow the seeds after two consecutive corn crops. This, however, would not generally be a good plan, as there would be a risk of the land being very foul and poor in condition after such a course of cropping.

There are three ways of sowing grass seeds for permanent pasture. They may be sown—

1. By themselves, in spring or in August or September.
2. With a corn crop in the spring, as is done commonly in rotation seeds.
3. With a forage crop in the spring.

When sown by themselves the result is usually very good, though in very dry seasons germination does not take place evenly, and there may sometimes be a failure of plant. As a general result of experiments with different kinds of grasses, Sinclair notes that of all the months of the year, August and September give the best results. If sown by themselves the seed should be put in early enough to avoid the risk of severe frost while it is still in its young stages of growth.

Where sown with a corn or forage crop the advantage gained is that the young seeds have shade from the sun and shelter from late frosts until harvest, by which time they have sufficient strength to withstand cold or drought. With a corn crop, however, the soil is exhausted, and after the corn is harvested, is poorer than when the seeds were first sown. Where a forage crop is used, and fed off lightly by sheep, the soil is enriched, and the droppings of the sheep act as a manure to the young seeds. Rape is a common plant to use for the purpose, being sown at the rate of some 3 or 4 lbs. per acre in the spring at about the same time as the grasses. It is fed off during the summer, care being taken not to keep the sheep too long on the ground, nor to feed off the crop in wet weather, for in either case the trampling would be injurious to the seeds. Rye and oats are also grown in the same way, to be fed off by sheep during the summer.

The seed should be sown, if possible, by drill, it being very important to cover the whole surface evenly, and, as in the case of temporary leys, to cover the seed at an even depth. It is also important to sow all the different kinds of seed evenly over the whole area, and this can only be done perfectly where they are sown in several lots. The most perfect results are obtained when the large-seeded plants, such as cocksfoot, foxtail, meadow fescue, tall fescue, etc., are sown in one lot; the small-seeded grasses, such as hard fescue, sheep's fescue, crested dog's-tail, etc., in another,

and the heavy seeds, such as the clovers, timothy, and yarrow, in a third. Each of these lots should be thoroughly mixed, and preferably they should be drilled in different directions, so as to make sure of covering the whole surface. After drilling a bush harrowing is given, and a light wooden rolling to compress the soil slightly about the seed. During the first autumn there will not usually be very much food produced for stock, but if the seed has been sown in the spring, and the summer has been a moist one, it may be lightly fed off by sheep, care being taken, as already noticed, to keep stock off the seeds in time of frost. In the following summer a crop of hay is usually cut, care being taken to mow very early in the season to prevent the plants from forming flower and seed, and to cause a thickening of the root and strengthening of the whole plant. The second crop is usually grazed, preferably by young cattle receiving a small allowance of concentrated food, but they should only be kept on the land in dry weather, so as to avoid injuring the young plants by treading. Sheep are sometimes used for the same purpose, but are objectionable in biting out the finest grasses and sometimes destroying them altogether, so that the large, coarse grasses are thus encouraged and the quality of the pasture permanently injured. In the autumn a light dressing of farmyard manure is applied, which acts in the double capacity of a manure to the plant and a protection against the cold, and this dressing will usually be repeated in subsequent years, depending, however, on the kind of stock grazing on the land, and the amount of extra food they obtain.

Grass land is occasionally laid down by the process of inoculation. This consists in planting small pieces of turf taken from old grass land on the surface and rolling them in. A seeding of Italian rye grass is then given over the whole, so as to fill up the spaces between the sets and increase the produce for the first year or two. It also serves the purpose in this case of preventing weeds from obtaining a hold in the large spaces between the sets. It is not desirable to pare old grass land in order to plant new, and the plan is therefore usually adopted of cutting narrow strips out of the old turf with a gripping plough and

chopping these up into small pieces ready for planting. The grips in the old grass soon heal up and little permanent injury is done. The system has the same objections as that of using hay-seeds, namely, that not only the natural grasses are introduced into the new pasture, but also the weeds of the old grass land. This system has not been followed to any considerable extent. It has been chiefly successful on stiff clays.

Apart from the question of manuring, the management of pasture land consists chiefly in so regulating the number and kinds of stock fed upon it as to keep the land grazed down evenly and prevent the undue preponderance of any one kind of plant. As already pointed out, sheep tend to destroy the finer plants in grass land, owing to their power of very close grazing, and horses also are bad grazers, for they rarely graze evenly over a pasture, usually feeding down part of the land quite bare and leaving a good deal altogether untouched. With other stock, however, they are often useful, as they will consume rough grasses which other animals will not eat. If a pasture is to be kept quite even it should be rather closely grazed as a rule, and the better condition the land is in and the stronger the growth of the grass the more heavily it should be stocked, otherwise the ranker, larger plants will increase at the expense of the finer ones. It is also important to remove from the pasture in the autumn the bents and rough growth that have not been consumed by the regular stock. In the case of the best pastures this is usually done by means of young store cattle, for of course such food is not good enough for fattening animals. If it is not convenient to graze off the bents, a mowing machine may be lightly run over the surface, so as to cut them off and roughly keep the grass level. Another cause of inconvenience in pastures is the rank growth caused by the droppings of cattle. The tufts caused in this way are rarely grazed by stock unless they are hard pressed by hunger, and so a very uneven surface is eventually produced. To avoid this, the droppings of stock should be spread at rather frequent intervals, and in some cases a clause to this effect is inserted in farm agreements. It is usual to chain-harrow the grass land in the spring, in order to remove any dead plants and withered,

useless material, and so to allow of a free growth of the grasses. It also has the effect of levelling the surface, particularly where mole-hills or ant-hills are common, and rolling is often done with the same object. The chain harrow is also used to collect straw or any other material of the kind that may have been left after the application of farmyard manure.

The manure required on pastures will vary according to the kind of stock chiefly fed upon them. Where fatting stock are kept, little manure, if any, will be required, and if the animals receive an allowance of concentrated food the land will be enriched so much by their droppings that no other manure will be required. Where dairy cattle are kept or young stock are reared, it will be necessary to manure the pastures, and phosphates, particularly, are found useful in such cases. Basic slag is a form of phosphatic manure commonly used, and frequently gives good results on grass land.

Meadows are usually grazed during the early part of the year, and some time in April or even May are shut up to allow of the growth of a crop for hay. They are usually chain-harrowed and rolled in the spring, so as to level the surface as perfectly as possible and prepare it for the mowing machine and tedder. The manure required depends on the plants present, nitrogenous manures encouraging the grasses and making them grow more strongly, while phosphates and potash manures encourage the growth of clovers and other leguminous plants. Farmyard manure is used to a very large extent and gives good results. It should, however, be used with discretion, and with reference to the condition of the grass. There is a tendency in meadows for the rank, strong grasses to overmaster the finer, smaller plants, and the quality of the produce gradually deteriorates. To avoid this it is a common practice to graze the land occasionally for a whole season, and it is inserted in many farm agreements that the grass land shall be grazed at least once in three years. This keeps the growth more even and prevents the development of large, coarse plants.

Haymaking.—With very few exceptions all plants should be cut for haymaking just when they are in full flower

After this the feeding material which the plant contains is gradually concentrated in the seed, and therefore the rest of the plant becomes poorer, and moreover the seed is likely to be lost in the process of haymaking. A considerable formation of woody material also takes place in the later stages of the plant's growth, and its digestibility suffers in consequence. The process of making meadow hay differs slightly from that of making clover hay. In the former case, after the crop is cut, either with a mowing machine or by hand, it is spread on the surface of the ground to dry. If any is cut in the later part of the day it will not usually be touched until the following morning, as there is no time to expose it to the sun and get it together before evening. The portion which is cut early and spread is usually got together into small wind-rows in the course of the afternoon, and these are put into small cocks, called grass-cocks or pooks, for the night. The object of putting the hay into cock during the night is to expose as small a surface as possible to the dew, which would otherwise bleach it and spoil its quality. In case of bad weather also the hay will suffer less in cock than if spread. The next morning, as soon as the ground is dry, the grass-cocks are opened and the hay spread abroad, and after some time has elapsed for drying, it is tedded or turned by hand and again allowed to dry. Towards the end of the day it is raked into wind-rows and finally put up into cocks a good deal larger than those of the previous night. On the following day the process is repeated, the cocks being spread after the ground has got dry, though not very widely, and if the weather is favourable and the crop is not a very heavy one the hay will probably be ready for carrying some time during the day. If the hay is not ready for carrying it is put into still larger cocks for the night, and will be carried on the following morning. The time when hay may be carried and put into rick depends on the bulk of the crop and its character, whether it contains a large amount of leaf and bottom growth, or whether it is stemmy and benty in its character. If the latter be the case the hay should be carried as soon as possible, and it will be greatly improved if a good deal of heating takes place in the rick.

In many districts it is the custom to put the hay up into summer ricks in the field, that is, small ricks containing, say, half a load or more each. This is an advantage in many respects, as it saves time in the most important part of the year, and the hay can be got together rather sooner than if it is to be put into a large rick, there being less chance of heating and more opportunity for drying in the summer ricks. The final carting and building into ricks may be delayed in this case for some weeks or even months, till any convenient opportunity. In building a rick great care has to be taken to keep the middle as high as possible, otherwise, as the hay settles together the thatch will become too flat and will not run the rain off rapidly enough. Hay-ricks are usually left unthatched for a time after they are put up, in order to allow the hay to heat and settle. They are then thatched with straw, or sometimes, where straw is valuable, a wooden or other cover is put over them.

In making clover hay the chief point of difference is that the crop must be handled very gently and turned as little as possible, so as to avoid breaking the leaf, which is the most valuable part of the plant for feeding purposes. The crop therefore remains in swath for a day or two after cutting, and is then gently turned over by hand, so as to allow the under-side to dry. Then, after an interval has elapsed it is turned back again and is then carted direct from the rows without putting into cock at all. In this way handling is avoided as much as possible, and the best result is obtained. In both meadow and clover hay, where the weather is unfavourable, the same principles must be followed, but the process will of course be prolonged and the final result will be inferior.

Ensilage.—This process of preserving fodder crops without previously drying them has long been known, though it is only a few years since it was first adopted in this country on a practical scale. When it was first practised, the fodder was always preserved in a silo, that is, a pit or building, which could be completely filled with the green crop and then heavily pressed. The expense, however, of making silos proved an obstacle to the adoption of the system, for it was found that when they had to be built,

the average cost was something like £1 per ton of their capacity.[1] More recently it has been found possible to make useful silage in stacks, and this has led to a wider adoption of the process, though it is still by no means common.

Two kinds of silage may be made, viz. sour and sweet, the former being produced chiefly where the silo system is adopted, the latter either in silos or stacks, depending upon the system of management. In making sour silage the crop is cut, filled into the silo, and weighted heavily at once so as to exclude the air as far as possible, and in this way to check fermentation and keep down the temperature. The resulting silage is dark-coloured, very sour, and with a strong, offensive smell, but usually it will keep for a long time after it is taken from the silo without turning mouldy. If sweet silage is required, the silo is filled slowly, layers of a few feet in thickness being put into it at intervals of some days, so as to allow the temperature to rise to between 125° and 140°. It is found that this temperature is sufficient to kill the bacteria which otherwise would turn the silage sour, and consequently but little formation of acid takes place, and a sweet, rather fragrant silage is produced, usually of a brown colour, but having the disadvantage that it usually becomes mouldy soon after it is taken from the silo. Sweet silage is usually produced in stacks, however they may be treated, but different parts of the stack will sometimes vary in this respect. It also depends to some extent upon the kind of crop and the condition in which it is got together.

In making silage in a silo the crop may either be put in in its natural condition, or it may be previously chaffed. The process of chaffing makes it easier to tread down the contents of the silo firmly, and less pressure is then requisite. With most crops, however, there is no absolute necessity for chaffing before putting into the silo, except where the fodder is rather over-ripe and stemmy or woody in its character. In any case the fodder must be well trodden down, horses being sometimes employed for the purpose, men being also required to tread down with special care about the sides and corners of the silo. If

[1] H. M. Jenkins, *Journal R.A.S.E.*, vol. xx. S.S.

this is not done there will be a great deal of waste at the sides from the silage becoming mouldy. When the silo is full it is weighted or pressed by some mechanical means, the pressure being on the average about 1 cwt. to the square foot. Care must be taken, however, not to press too heavily, or the juices of the plant will be pressed out and may be wasted. Systems of compressing the silage which give a following pressure are preferable, for otherwise the silos require constant attention at first, owing to the rapidity with which their contents sink in the process of fermentation. Should the pressure be relaxed for any length of time the silage will be completely spoilt.

In making silage in stacks the crop is of course got together in its long state, unchaffed, and in building care must be taken to consolidate the sides of the stack as much as possible, otherwise very great loss will ensue. Pressure is then applied, either by weights or by screws or levers, care being taken in this case, as in that of silos, not to press too heavily. There is more waste of fodder in the stack than in the silo system, as some inches round the sides are almost always worthless, but the superior convenience and economy of the stack system counterbalance this disadvantage.

Silage is useful food for all kinds of stock. When it is used for cows in milk care has to be taken that the milk shall not be exposed to the smell of the silage, or it will become tainted in a very short time. It has been found, however, that the mere fact of the cows being fed on silage will not give the milk any unpleasant flavour if it is not exposed to the smell. In experiments carried out at Woburn for the purpose of comparing silage as a feeding stuff with roots and hay-chaff, the results varied according to the materials from which the silage was made. In another experiment for the purpose of comparing the food value of grass made into silage with that of similar grass made into hay, under favourable conditions, it was found that 2·4 acres of grass made into silage produced the same feeding results as 2·8 acres made into hay. Most of the ordinary forage crops may be used for making silage, but those which are woody or have strong, large stems are objectionable, as they do not readily press together. Fre-

quently rough growth about roadsides and hedgerows is made into silage, and will make a fairly valuable fodder for stock. It must not be supposed, however, that the process of ensilage will convert poor feeding material into valuable fodder of a high feeding value.

CHAPTER XXX

WEEDS

A WEED is usually described as "a plant out of place," and all weeds on farm land are harmful, because they consume plant food which would otherwise be available for the crops. Some weeds may also do harm by smothering the crop amongst which they grow.

From an agricultural point of view the weeds of the farm may be divided into two classes :—

1. Annual weeds, chiefly shallow-rooted.
2. Biennial or perennial weeds, chiefly deep-rooted.

Amongst the former class the following occur in arable land :—

Blue Bottle (*Centaurea cyanus*).
White Campion (*Lychnis vespertina*).
Corn Chamomile (*Anthemis arvensis*).
Charlock (*Sinapis arvensis*).
Chickweed (*Stellaria media*).
Corn Cockle (*Agrostemma githago*).
Corn Poppy (*Papaver rheas*).
Fat Hen (*Chenopodium album*).
Fools' Parsley (*Æthusa cynapium*).
Fumitory (*Fumaria officinalis*).
Goose Grass (*Galium aparine*).
Groundsel (*Senecio vulgaris*).
Pimpernel (*Anagallis arvensis*).
Scorpion Grass (*Myosotis arvensis*).
Shepherd's Purse (*Capsella bursa pastoris*).
Spurrey (*Spergula arvensis*).

And many of the grasses already described, especially couch, which, however, is a perennial plant.

In pastures:—

Mouse-Eared Chickweed (*Cerastium triviale*).
Yellow Rattle (*Rhinanthus crista-galli*).

These plants maintain their position in the soil by their copious production of seed, and it is therefore easy to understand why most of them are weeds of arable rather than grass land, for in the latter there is much less opportunity for the germination and growth of seeds, especially upon the surface, than there is in arable land. Another way in which these plants often appear in the fields is by the power of their seeds to remain dormant in the soil for a long time, so that even after a considerable time, when they are placed under conditions favourable for germination, the seeds begin to grow, and a crop of weeds will result. The common charlock or kedlock is a familiar example of this, the seed frequently remaining for a very long time in the soil, eventually growing strongly when brought to the surface.

When weeds occur in a growing crop the chief method of cleaning the land is to prevent their seeding as far as possible by hoeing, or, as in the case of charlock, by cutting their heads off, if possible. If the land be free from crop as many weed seeds as possible should be made to germinate, by stirring the soil or ploughing it rather shallow, and when growth has commenced the weeds may be killed by the use of cultivators, drags, and harrows. They may then be collected and burnt, if necessary. In heavy land, however, the above system is not so easy to follow, and the usual plan of cleaning the land is by ploughing and working it until the soil is in a rough, cloddy condition, and then to kill the weeds in the clods by keeping the latter as dry as possible, frequently turning them over with the drags. In very heavy land bare fallowing may be necessary, and on some soils bare fallowing is a regular part of the farm work, for it is found that otherwise the soil becomes of a texture very difficult to work, and very full of weeds, especially after a series of wet years. The work of bare fallowing consists essentially of repeated ploughing whenever the weather is favourable, taking great care never to reduce the soil to a fine tilth. Bastard fallows are also frequently employed, the fallowing being done at the end of the

summer after the growth of some crop, such as vetches. The soil is thus left bare and unproductive for a shorter time.

Where creeping weeds, such as couch, occur, they may be conveniently dealt with by forking by hand, unless they exist in very large quantities. "Raftering" is sometimes adopted in very light land, that is, ploughing every other fallow and cleaning the soil so turned over, and then cross-ploughing and cleaning thoroughly again. There is no particular advantage in this system, and it usually takes rather longer than when the whole surface is ploughed at once.

Of the biennial and perennial weeds the following are the most important:—

In arable land—

Bindweed (*Convolvulus arvensis*).
Coltsfoot (*Tussilago farfara*).
Crane's-bill (various species of *Geranium*).
Dock (*Rumex obtusifolius*).
Garlic (*Allium oleraceum*).
Horsetail (*Equisetum arvense*).
Knot Grass (*Polygonum aviculare*).
Sow Thistle (*Sonchus arvensis*).
Speedwell (*Veronica officinalis*).

In grass land—

Bedstraw (*Galium palustre*).
Buttercup (various species of *Ranunculus*).
Crow Garlic (*Allium vineale*).
Daisy (*Bellis perennis*).
Dandelion (*Leontodon taraxacum*).
Knapweed (*Centaurea nigra*).
Ladies' Smock (*Cardamine pratensis*).
Meadow Saffron (*Colchicum autumnale*).
Moss (various species).
Nettle (*Urtica dioica*).
Ox-eye Daisy (*Chrysanthemum leucanthemum*).
Plantain (*Plantago media*).
Rest Harrow (*Ononis arvensis*).
Rushes (various species).
Sheep's Sorrel (*Rumex acetosella*).
Silver Weed (*Potentilla anserina*).
Thistle (*Carduus*, various species).

Besides the methods mentioned above for destroying weeds it is important in the case of biennial or perennial plants to prevent, as far as possible, the formation of leaves,

for when this is done the plant is unable to feed on the air, and store up plant food for future use. Accordingly, by repeated cutting it is eventually so weakened that it finally dies out. Thus, constant cutting of such plants as thistles, so as to destroy their leaves and prevent their forming seed, is a most important part of the management of grass land where they occur commonly. In a similar way constant ploughing destroys the deep-rooted coltsfoot, by preventing the plant storing up food in its thick, fleshy root. It must *be understood, however, that in both these cases a single* cutting or ploughing is not sufficient, and the process needs to be repeated frequently, sometimes for several years. Plants which have thick, fleshy roots, such as the coltsfoot, dock, etc., may be kept down by collecting the roots by hand in the corn, early in the spring, before they have had an opportunity of forming seed. At that time of year the roots have usually little hold of the ground, and are often seen on the surface of the soil, to which they have been brought in the process of cultivation.

Another very important point with regard to the suppression of weeds is the use of pure seed, particularly those of clovers and grasses. If a mixture of permanent grass seed contains only 1 per cent of weeds it will add to the soil something like thirty to forty weed seeds per square yard of surface. It should also be remembered that weed seeds contained in "cavings" or cleanings from seeds, if mixed with manure, are frequently not destroyed, but will be carted on to the land with the manure, and so give trouble later on amongst the crops.

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